**3GPP TSG RAN WG1 Meeting #104-e R1-21xxxxx**

**E-Meeting, January 25th – February 5th, 2021**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #2 on 104-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 [2-12]

[103-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: 11/5
* 2nd check point: 11/10
* 3rd check point: 11/12

# Issues

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

### Issue 1: The TBS table.

The following are proposed:

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

|  |  |
| --- | --- |
| **I\_TBS** | **I\_SF** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | ~~[~~552, ~~536]~~ | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | ~~[~~328, ~~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 | ~~[~~2472~~, 2536]~~ | 2984 | 4008 | 4968 |

 |
| [3] | **Proposal 1: Confirm the following working assumptions from RAN1#103-e –*** **The following TBS indices are introduced for downlink**

|  |  |
| --- | --- |
| **I\_TBS** | **I\_SF** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | [552, 536] | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | [328, 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 | [2472, 2536] | 2984 | 4008 | 4968 |

**Proposal 2: For downlink, select the following TBS values –*** **I\_TBS=14, I\_SF=1 : TBS=552**
* **I\_TBS=16, I\_SF=0 : TBS=328**
* **I\_TBS=21, I\_SF=4 : TBS=2472**
 |
| [4] | ***Proposal 1: Confirm the working assumption for DL TBS table for NB-IoT 16QAM.**** $0\leq I\_{TBS}\leq 21$ ***for guard-band and standalone deployment***
* $0\leq I\_{TBS}\leq 17$ ***for in-band deployment***

Table 1: New TBS entries for DL 16QAM

|  |  |
| --- | --- |
| **I\_TBS** | **I\_SF** |
| **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 |

***Proposal 2: I\_SF > 7 is not supported for DL TBS table for NB-IoT 16QAM.*** |
| [6] | ***Proposal 1: Confirm the TBS table working assumption with reusing the legacy TBS entry in LTE TBS table.*** |
| [7] | Observation 1: Supporting N\_SF=14, will increase in-band peak DL data rate from 181 to 207kbps (+14.3%)Observation 2: For the guard-band and standalone scenarios, supporting N\_SF=14 will improve data rate by 14.3% in most coverage conditions.Observation 3: Higher N\_SF values can be signaled without increasing DCI size.Proposal 1: Support additional N\_SF values of 12 and 14. • FFS: DCI changes |
| [8] | **Proposal 1: Confirm the working assumption for the DL TBS table, with the following modifications:*** **Entry [328, 296] is replaced by 296.**
* **Entry [552, 536] is replaced by 552.**
* **Entry [2472, 2536] is replaced by 2472.**
 |
| [9] | **Proposal 1: Confirm the Working Assumption referring to 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 avoid a performance overlapping issue, between [552, 536] the TBS = 536 bits is selected, and**
* **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 WA on the TBS Table for UL accounts for this exact change, which is an ability that DL should also have.**

**Figure A.1: For stand-alone and guard-band deployments using 16-QAM, the legacy LTE TBS = 552 bits and TBS = 328 bits cause in NB-IoT a performance overlapping and crossing issue respectively (See dotted circles).** |

#### Round-1 proposals and discussion

All companies agree to confirm the working assumption for downlink TBS.

For the values in brackets, there are following proposals:

* Reuse the LTE table, i.e., TBS=552bits for I\_TBS=14, I\_SF=1; TBS=328bits for I\_TBS=16, I\_SF=0; TBS=2472bits for I\_TBS=21, I\_SF=4
	+ Huawei, HiSilicon, Nokia, NSB, ZTE, Lenovo, Moto,
* TBS=552bits for I\_TBS=14, I\_SF=1; TBS=296bits for I\_TBS=16, I\_SF=0; TBS=2472bits for I\_TBS=21, I\_SF=4
	+ QC
* TBS=536bits for I\_TBS=14, I\_SF=1; 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 with following modifications:

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 14 | 256 | ~~[~~552~~, 536]~~ | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | [328, 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 | ~~[~~2472~~, 2536]~~ | 2984 | 4008 | 4968 |

* **FFS for I\_SF > 7**

Proposal 2: Down-select in this meeting on the TBS:

* **Between [328, 296] for I\_TBS=16, I\_SF=0**

Proposal 3: I\_SF>7 is not supported in Rel-17.

Please input your comments for the above proposals:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support the three proposal, and hope to reuse the legacy LTE MCS table fully. |
| Ericsson | On Proposal 1 and 2:LTE would be our preference as well the problem is that for NB-IoT on “ITBS = 16, ISF = 0 → [328, 296]” and “ITBS = 14, ISF = 1 → [552, 536]” performance crossing and overlapping issues have been identified, that is why using the smaller TBS entries among the two choices in each case (i.e., “TBS = 296 bits” and “TBS = 536 bits”) is proposed as to eliminate the issues.For “ITBS = 21, ISF = 4 → [2472, 2536]” choosing TBS = 2536 bits will make possible to transmit the max Rel-16 TBS with half of the time-domain resources when 16-QAM is used. The WA for UL accounts for this exact change, which is an advantage that DL should also have.On Proposal 3:We are fine. |
| Nokia, NSB | We are fine with all three proposals. On proposal 2, our preference is to use the existing LTE value. |
| Qualcomm | We are OK with the three proposals. |
| Huawei, HiSilicon | Support the three proposals, and prefer to reuse the legacy LTE MCS table with 328 forI\_TBS=16, I\_SF=0. |
| MTK | We are fine with the 3 proposals and prefer legacy LTE MCS table. |
| ZTE,sanechips | OK with the three proposals. For proposal 2, we propose to reuse LTE TBS 14~21 without change. |

The following have been achieved:

**Working Assumption**

The previous working assumption on the following TBS indices for downlink is updated with following modifications:

|  |  |
| --- | --- |
|  |  |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | ~~[~~552~~, 536]~~ | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | [328, 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 | ~~[~~2472~~, 2536]~~ | 2984 | 4008 | 4968 |

* FFS for I\_SF > 7

**Agreement**

I\_SF>7 is not supported in Rel-17.

#### Round-2 proposals and discussion

For the TBS for the downlink, there is still one entry subject to down-selection and one entry in yellow.

For entry I\_TBS=16, I\_SF=0, the proposals are

* TBS=328bits
	+ Huawei, HiSilicon, Nokia, NSB, ZTE, Lenovo, Moto, MTK
* TBS=296bits
	+ Ericsson, QC

For entry I\_TBS=21, I\_SF=4, the proposals are

* TBS=2472bits
	+ Huawei, HiSilicon, Nokia, NSB, ZTE, Lenovo, Moto, QC, MTK
* TBS=2536bits
	+ Ericsson

The reasons to reuse the legacy LTE TBS table include reusing the LTE TBS values instead of new values, little performance impact, coding rate closer to other values in a row (for I\_TBS=21, I\_SF=4). The reasons to use the values different the legacy LTE TBS table include coding rate closer to other values in a row (for I\_TBS=16, I\_SF=0), performance crossing, max Rel-16 TBS transmission with half of the time-domain resources.

Considering the differences between the options are very small, and the majority view supports to reuse the legacy TBS table, the following is proposed:

**Proposal 1.1:**

**The previous working assumption on the following TBS indices for downlink is updated with following modifications:**

|  |  |
| --- | --- |
|  |  |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | ~~[~~552~~, 536]~~ | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | ~~[~~328~~, 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 | ~~[~~2472~~, 2536]~~ | 2984 | 4008 | 4968 |

* ~~FFS for I\_SF > 7~~

Please input your further comments for the above proposals:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | Support the proposal. |
| Ericsson | In relation with the down-selection between [328, 296], Ericsson got the action point of investigating why a performance crossing issue with respect to the TBS = 336 bits was observed when the TBS = 328 bits is chosen.On this matter, we performed several simulations using a different Simulator which provided the following results:

|  |  |
| --- | --- |
| 328bits,10%BLER | 336bits,10%BLER |
| 9.9dB | 9.64dB |
| 9.88dB | 9.64dB |
| 9.87dB | 9.64dB |
| 9.88dB | 9.64dB |
| 9.87dB | 9.64dB |

As you can see, the performance crossing issue was also observed since the performance of TBS = 328 bits is crossing-out the one of the TBS = 336 bits. Investigating a bit further on the processing chain, apparently the “soft-demapper module” and Viterbi decoding algorithms sometimes produce a response that is non-linear and that produces an unusual performance when the coding rates are nearly close. As we have shown in our contribution, the issue is not observed when instead of a TBS = 328 bits a TBS = 296 bits is utilized.From three TBS entries surrounded by brackets (i.e., [328, 296], [552, 536], and [2472, 2536]), we were fine with [552, 536] (although there is an overlapping there is no crossing issue), but choosing for the other two [296] and [2536] will be beneficial for the 16-QAM feature in terms of avoiding a performance issue and saving resources in the time-domain (50% with respect to Rel-16) respectively. |
| MTK | Support the proposal. |
| Huawei, HiSilicon | Support |
| Nokia, NSB | We support the proposal. We are also fine to leave as working assumption to allow other companies to check the performance for next meeting. |
| QC | Can’t we select 296 in the first column? |
| ZTE,sanechips | Support.  |
| FL summary | Although companies are aware of the evaluations, the majority view is still to use the legacy TBS table. Could it be acceptable to be a working assumption, so that we can further revisit/confirm it in next meeting?**Proposed working assumption 1.1:****The previous working assumption on the following TBS indices for downlink is updated with following modifications:**

|  |  |
| --- | --- |
|  |  |
| **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~~, 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 | ~~[~~2472~~, 2536]~~ | 2984 | 4008 | 4968 |

* ~~FFS for I\_SF > 7~~
 |

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

The following are proposed:

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | Proposal 2: Confirm the following WA* **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16QAM.**

Proposal 3: Confirm the WA with following revisions.* **For inband deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and ~~[~~17~~]~~ are used for 16QAM.**

**Figure 1. NPDSCH BLER of QPSK vs. 16QAM with Isf = 4, ITBS=14/15, 1T1R, AWGN channel for standalone/guard-band deployments****Figure 2. NPDSCH BLER of QPSK vs. 16QAM with Isf = 4, ITBS=14, 15, 2T1R, AWGN for standalone/guard-band deployments****Figure 3. NPDSCH BLER of in-band deployment ITBS=10, 11 QPSK vs. 16QAM with 1T1R and Isf = 4 in AWGN****Figure 4. NPDSCH BLER of in-band deployment ITBS=10, 11 QPSK vs. 16QAM with 2T1R and Isf = 4 in AWGN** |
| [3] | **Proposal 1: 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 16QAM.**
* **For inband deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and [17] are used for 16QAM.**

**Proposal 3: For in-band deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and 17 are used for 16-QAM.**Figure 2. NPDSCH performance with 16-QAM. |
| [4] | ***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 close to 1 dB better than QPSK performance at BLER =0.1 for standalone deployment when TBS 13 (2536 bits with ISF=7) is used.******Proposal 3: For standalone and guard-band deployment, 16QAM can be used for TBS indexes from 12 to 21.******Observation 3: For NPDSCH with 1T1R antenna, 16QAM performance is better than QPSK performance at BLER=0.1 for in-band deployment when TBS 10 (1736 bits with ISF=7) is used.******Proposal 4: For in-band deployment, 16QAM can be used for TBS indexes from 10 to 17.***Figure 1 BLER performance for NPDSCH with 1T1R in standalone deploymentFigure 2 BLER performance for NPDSCH with 2T1R in standalone deploymentD:\代码\NB-IoT\16QAM\0924-1.pngFigure 3 BLER performance of NPDSCH in in-band deployment |
| [6] | ***Proposal 2: Confirm the TBS breaking point work assumption with removing the bracket.*** |
| [8] | **Proposal 2: Confirm the working assumption regarding TBS applicability for different deployment scenarios with the following modification:*** **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16QAM.**
* **For inband deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and ~~[~~17~~]~~ are used for 16QAM.**

**Table 4 SNR needed for 10% BLER in different deployment scenarios, and the corresponding “bits/RE”. Highlighted in red, the TBSs that have a better performance with 16-QAM than with QPSK. Note that “bits/RE” is twice the coding rate for QPSK.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | IB2ports | Bits/RE | IB4ports | Bits/RE | Standalone | Bits/RE |
| 888, ModOrder 16 | 7.74 | 1.71 | 8.03 | 1.78 | 5.63 | 1.11 |
| 888, ModOrder 4 | 7.63 | 1.71 | 7.97 | 1.78 | 3.88 | 1.11 |
| 904, ModOrder 16 | 7.90 | 1.74 | 8.14 | 1.81 | 5.33 | 1.13 |
| 904, ModOrder 4 | 7.85 | 1.74 | 8.83 | 1.81 | 3.94 | 1.13 |
| 920, ModOrder 16 | 8.09 | 1.77 | 8.47 | 1.84 | 5.40 | 1.15 |
| 920, ModOrder 4 | 7.99 | 1.77 | 10.57 | 1.84 | 4.03 | 1.15 |
| 936, ModOrder 16 | 8.26 | 1.80 | 8.55 | 1.87 | 5.76 | 1.17 |
| 936, ModOrder 4 | 8.74 | 1.80 | NaN | 1.87 | 4.28 | 1.17 |
| 1400, ModOrder 16 | 11.69 | 2.69 | 11.99 | 2.80 | 8.17 | 1.75 |
| 1400, ModOrder 4 | NaN | 2.69 | NaN | 2.80 | 8.01 | 1.75 |
| 1416, ModOrder 16 | 11.78 | 2.72 | 12.00 | 2.83 | 8.33 | 1.77 |
| 1416, ModOrder 4 | NaN | 2.72 | NaN | 2.83 | 8.38 | 1.77 |

 |
| [9] | **Observation 1 Based on simulation results the second Working Assumption referring** **to the use of TBS entries encompassed by ITBS indices between 14 and 21 can be confirmed from a stand-alone/guard-band deployments perspective.****Proposal 2 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 3 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 4 In line with the Working Assumptions, 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 | 536 | 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 2 Based on simulation results the second Working Assumption referring to the use of TBS entries encompassed by ITBS indices between 11 and 17 can be confirmed from an in-band deployment perspective.Proposal 5 Confirm the Working Assumption referring to the use of 16-QAM for the TBS entries encompassed by ITBS indices between 11 and 17 for the in-band deployment.**Proposal 6 The TBS/MCS Table for in-band deployments uses as breaking point ITBS = 10 as last ITBS index for QPSK and ITBS = 11 as first ITBS index for16-QAM.****Proposal 7 In line with the Working Assumptions, 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 | 536 | 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 | - | - | - | - | - | - | - | - |
| 21 | - | - | - | - | - | - | - | - |

**Figure 1: 10% BLER for all TBS entries encompassed by the ITBS indices between 14 and 21 for stand-alone and guard-band deployments.**In order to know the suitability of such a breaking point, we evaluated the average SINR difference between those ITBS indices:* ITBS14\_16QAMavg-to-ITBS13\_QPSKavg = abs(8.94 dB – 8.28 dB) ⁓ 0.66 dB.

where:ITBS14\_16QAMavg and ITBS13\_QPSKavg refer to the average SINR across all the TBS entries in the rows associated to ITBS 14 for 16-QAM and ITBS 13 for QPSK respectively.The resulting average SINR difference between ITBS = 13 which uses QPSK and ITBS = 14 which uses 16-QAM resulted to be smaller than 1 dB (i.e., ⁓ 0.66 dB), hence is suitable to have as breaking point ITBS = 13 as last ITBS index for QPSK and ITBS = 14 as first ITBS index for16-QAM for stand-alone/guard-band deployments. |
| [12] | **Observation 1 Based on simulation results the second Working Assumption referring to the use of TBS entries encompassed by ITBS indices between 14 and 21 can be confirmed from a stand-alone/guard-band deployments perspective.****Observation 2 Based on simulation results the second Working Assumption referring to the use of TBS entries encompassed by ITBS indices between 11 and 17 can be confirmed from an in-band deployment perspective.** |

#### Round-1 proposals and discussion

For the working assumptions on breaking points, there are following proposals:

* Confirm the working assumption and remove the brackets
	+ Huawei, HiSilicon, Nokia, NSB, Lenovo, Moto, QC, Ericsson
* For standalone and guardband deployments, downlink TBS entries between 12 and 21 are used for 16QAM; for inband deployment, downlink TBS entries between 10 and 17 are used for 16QAM.
	+ ZTE

Based on the input, the following is proposed

Proposal 4: Confirm the working assumption with following modifications:

* **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16QAM.**
* **For inband deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and ~~[~~17~~]~~ are used for 16QAM.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support the proposal 4 |
| Ericsson | We are fine, under the understanding that proposal 4 means:* For stand-alone and guard-band deployments: The TBS entries used for 16-QAM in DL span from I\_TBS = 14 to I\_TBS = 21 and I\_SF = 0 to I\_SF = 7, being in terms of breaking-point I\_TBS = 13 the last I\_TBS index used for QPSK and I\_TBS = 14 the first I\_TBS index used for16-QAM.
* For in-band deployments: The TBS entries used for 16-QAM in DL span from I\_TBS = 11 to I\_TBS = 17 and I\_SF = 0 to I\_SF = 7, being in terms of breaking-point I\_TBS = 10 the last I\_TBS index used for QPSK and I\_TBS = 11 the first I\_TBS index used for16-QAM.
 |
| Nokia, NSB | We support FL’s proposal |
| Qualcomm | We support the proposal. |
| Huawei, HiSilicon | Support the proposal 4 |
| MTK | We are ok for propoas4 and Ericsson’s clarification. |
| ZTE,sanechips | Disagree.The breaking point has an impact on the NPDSCH performance. We have the following 2 concerns:1. For selecting the breaking point, the simulation results based on AWGN can not reflect the real channel condition.
2. The selection of braking point should be similar with LTE design, which also should be based on the fading channel for simulation.

According to our simulation results for standalone and guardband deployments, 16QAM can be used for TBS indexes from 12 to 21 for guard-band/standalone deployment. And overlapped TBS 12 and 13 could be set for MCS entries with QPSK and 16QAM to be used for different configurations and scenarios. For in-band deployment, 16QAM can be used for TBS indexes from 10 to 17.Obviously, if we do not consider the fading channel to determine the breaking point, a significant performance loss will be expected for some cases. Additionally, if 5 bit MCS table is adopted, the reserved states can be used to indicate the overlapped MCS entries, e.g.,TBS 12 and 13 to improve the transmission performance. Therefore, the overlapped MCS entries should not be precluded at present. |

#### Round-2 proposals and discussion

For the working assumptions on breaking points, there are following proposals:

* Confirm the working assumption and remove the brackets
	+ Huawei, HiSilicon, Nokia, NSB, Lenovo, Moto, QC, Ericsson
* For standalone and guardband deployments, downlink TBS entries between 12 and 21 are used for 16QAM; for inband deployment, downlink TBS entries between 10 and 17 are used for 16QAM.
	+ ZTE

The following can be observed from simulations of companies:

* For standalone and guardband deployments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TBS indexes | 12 | 13 | 14 | 15 |
| [2] |  |  | 16QAM < QPSK (0.6dB~1.2dB gap)coding rate reaches 0.95 for 2T1R | 16QAM > QPSK (0.5dB gap) |
| [3] |  | 16QAM < QPSK (0.5dB~0.5dB gap) | coding rate reaches 0.95 |  |
| [4] | 16QAM > QPSK (1.8dB gap for 1T1R) | 16QAM > QPSK (1dB gap for 2T1R) |  |  |
| [8] |  | 16QAM < QPSK (0.7dB gap) | 16QAM > QPSK (0.05dB gap) |  |
| [9] |  |  |  | average SINR difference between ITBS = 13 QPSK and ITBS = 14 16-QAM is smaller than 1dB (0.66dB) |

* For inband deployment

|  |  |  |  |
| --- | --- | --- | --- |
| TBS indexes | 10 | 11 | 12 |
| [2] | 16QAM < QPSK (2~2.5dB gap) | Coding rate reaches 0.95 for 1T1R, and not applicable for 2T1R. |  |
| [4] | 16QAM > QPSK(1dB gap) |  |  |
| [8] | 16QAM < QPSK (0.1~0.5dB gap) | QPSK is not applicable. |  |
| [9] |  | average SINR difference between ITBS = 10 QPSK and ITBS = 11 16-QAM is smaller than 1dB (0.9dB) |  |

In summary, companies ([2][3][8]) observed that QPSK is better with coding rate up to 0.85~0.95. And one company [4] observed that 16QAM is better when coding rate for QPSK reaches about 0.8.

As there’s no change on preferences in comments, the following is proposed based on the majority view:

Proposal 4.1: Confirm the working assumption with following modifications:

* **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16QAM.**
* **For inband deployments, the downlink TBS entries between 11 (TBS of 2024 for I\_SF=7) and ~~[~~17~~]~~ are used for 16QAM.**

Please input your further comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | Support the proposal |
| Ericsson | The proposal is ok with us. |
| MTK | Support the proposal. |
| Huawei, HiSilicon | Support |
| Nokia, NSB | We support the proposal |
| QC | We support the proposal |
| ZTE,sanechips | Disagree. The simulation results should be based on fading channel, instead of only the AWGN channel. |
| FL summary | With the evaluations, majority view is still to confirm the working assumption.In addition, at the beginning of LTE, it seems AWGN channel is assumed to determine the modulation as below, i.e., the CQI is generated through AWGN channel, and MCS table is generated based on CQI table.(RAN1#51)* AWGN channel is assumed for generating the CQI table
	+ Selection of exact set of MCS tables should take into account the discussion on the upper limit of the channel coding rate.

(RAN1#51bis)* RB alloc + MCS 🡆 TB size
	+ Supported MCSs include those used in CQI reporting

…* Size of MCS table
	+ CQI MCS values taken as a starting point for design
 |

### Issue 3: Applicability

The following are proposed on scheduling of TBS and modulation:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 4: Repetition of 2 is not supported for 16-QAM in DL.****Figure 5. NPDSCH standalone deployment with 1T1R in AWGN channel** |
| [3] | **Proposal 5: Support 16-QAM with repetition of 2 in the DL.**Figure 2. NPDSCH performance for 16-QAM with repetition. |
| [4] | ***Proposal 8: Repetition of 2 could be supported for DL 16QAM.***Table 5: DL peak data rate for 2 progresses

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Deployment scenario | Modulation order and Transport block size | Number of repetitions | Period of 2-progress transmission (ms) | Data rate (kbps) |
| Guard-band/ Standalone | Rel-16, QPSK, 2536 | 1 | 40 | 126.8 |
| 16QAM, 4968 | 2 | 60 | 165.6 |
| In-band | Rel-16, QPSK, 1736 | 1 | 40 | 86.8 |
| 16QAM, 3624 | 2 | 60 | 120.8 |

 |
| [5] | **Proposal3: no repetition for 16QAM.****Table 3: Typical cases for repetition investigation****Figure3: BLER on 1ms and 2ms RU****Figure4: BLER on 2ms and 4ms RU****Figure5: BLER on 5ms and 10ms RU** |
| [6] | ***Proposal 3: Repetition number of 2 is supported in case of 16QAM for downlink.*** |
| [7] | ***Proposal 2: Repetition=2 is not supported with 16QAM*** |
| [8] | **Proposal 3: DL 16-QAM is only applicable for NPDSCH scheduled from a DCI with CRC scrambled by C-RNTI.*** **At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.**

**Proposal 4: 16-QAM NPDSCH is only supported for R=1.** **- FFS whether to support the new TBSs with QPSK and increased RU**  |
| [9] | **Observation 3 The use-case for supporting 2 repetitions in DL was claimed “*to increase data rate for UEs that may not have sufficient SNR to use 16QAM*”. Looking at the TBS Table under WA, only the largest TBS entries may be the use-case for it since for the other TBS entries there are alternative TBS entries using QPSK with 1 repetition which will require less sinr.****Observation 4 According with simulations using 16-QAM with 2 repetitions, for the largest TBS entries the required sinr is in the range from ⁓ 6.45 dB to ⁓ 10.43 dB, which doesn’t seem to be sufficiently small as to suit a scenario where the UE doesn’t have sufficient SNR to use 16-QAM.****Proposal 8 Analyse the required sinr range for the use-case(s) of using 16-QAM with 2 repetitions as to determine its suitability. Discuss potential impacts on the channel quality reporting if the 2 repetitions case for 16-QAM were supported.****Figure A.2: BLER performance for 16-QAM in DL using 2 repetitions.**

|  |  |
| --- | --- |
| **16-QAM TBS entries** | **BLER performance for 16-QAM using 2 repetitions** |
|

|  |  |
| --- | --- |
| I\_tbs | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| 14 | 256 | 536 | 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 | 344 | 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 |

 |

|  |  |
| --- | --- |
| I\_tbs | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| 14 | 4.46 | 5 | 5.68 | 6.27 | 5.71 | 6.11 | 6.57 | 6.45 |
| 15 | 5.1 | 5.58 | 5.85 | 6.27 | 6.2 | 6.09 | 6.76 | 6.89 |
| 16 | 5.98 | 5.97 | 6.45 | 6.38 | 6.68 | 6.5 | 7.09 | 7.18 |
| 17 | 6.23 | 6.63 | 7.27 | 7.04 | 7.23 | 7.79 | 7.62 | 7.79 |
| 18 | 7.02 | 7.39 | 7.46 | 7.53 | 7.93 | 8.02 | 8.13 | 8.37 |
| 19 | 7.7 | 8.16 | 8.36 | 8.6 | 8.89 | 8.84 | 9.05 | 8.92 |
| 20 | 8.43 | 8.79 | 9.33 | 9.27 | 9.46 | 9.6 | 9.63 | 9.66 |
| 21 | 9.66 | 10.01 | 9.79 | 9.99 | 10.38 | 10.17 | 10.35 | 10.43 |

 |

 |
| [12] | **Observation 3 According with simulations using 16-QAM with 2 repetitions, for the largest TBS entries the required sinr is in the range from ⁓ 6.45 dB to ⁓ 10.43 dB, which doesn’t seem to be sufficiently small as to suit a scenario where the UE doesn’t have sufficient SNR to use 16-QAM.** |

#### Round-1 proposals and discussion

On whether 2 repetitions can be used for downlink 16-QAM, there are following proposals:

* Repetition of 2 can be supported for DL 16QAM
	+ Nokia, NSB, ZTE, Lenovo, Moto
* Repetition of 2 is not supported for DL 16QAM
	+ Huawei, HiSilicon, MTK, Sierra Wireless, QC
* Further analysis on suitability based on simulation
	+ Ericsson

Based on the inputs, the following is proposed

Proposal 5: Repetition of 2 is not supported for 16-QAM in downlink.

There is also proposal that 16-QAM is only for NPDSCH scheduled from a DCI with CRC scrambled by C-RNTI. Then it is proposed:

**Proposal 6: DL 16-QAM is only applicable for NPDSCH scheduled from a DCI with CRC scrambled by C-RNTI.**

* **At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | For proposal 5, our preference is support repetition of 2, the performance gain is verified in Rel.13 eMTC. At least we should get conclusion based on further results.Support proposal 6. |
| Ericsson | On Proposal 5:We are not supportive until the required sinr range for the use-case(s) of using 16-QAM with 2 repetitions has been analyzed as to determine its suitability, and we also need discuss potential impacts on the channel quality reporting if the 2 repetitions case for 16-QAM were supported. On Proposal 6:We are ok. |
| Nokia, NSB | On proposal 5, we support repetition of 2 and therefore do not agree with this proposal. Repetition can be used to increase data rate and it should be possible for the eNB to have this possibility.We are fine with proposal 6. |
| Qualcomm | We support both proposals. On DL repetition for 16-QAM, a better performance would be achieved by increasing the RU for QPSK in a factor of two. If we want to enable that use case, that should be the way to do it. |
| Huawei, HiSilicon | Support proposal 5 and 6. And we can also add the same FFS as the uplink, i.e. FFS: Applicability of 16-QAM for PUR or EDT. |
| MTK | We support 2 proposals. According to our simulation, both of QPSK and 16QAM without repetition can achieve better performance than 16QAM with repetition. Even for **I\_SF=7** case in which 16QAM with repetition can achieve higher data rate than QPSK, we can chose 16QAM without repetition to get better performance.  |
| ZTE,sanechips | For proposal 5, we prefer 16QAM with repetition of 2 to be supported. Considering HARQ-ACK, NPDCCH and NPDSCH delay, 16QAM with 2 repetitions can provide higher DL data rate for 10 SFs in a certain SNR range. For proposal 6, we are OK. |

The following has been achieved:

**Agreement**

DL 16-QAM is applicable for NPDSCH scheduled from a DCI with CRC scrambled by C-RNTI.

* At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.
* FFS: Applicability of 16-QAM for PUR.

#### Round-2 proposals and discussion

On whether 2 repetitions can be used for downlink 16-QAM, there are following proposals:

* Repetition of 2 can be supported for DL 16QAM
	+ Nokia, NSB, ZTE, Lenovo, Moto
* Repetition of 2 is not supported for DL 16QAM
	+ Huawei, HiSilicon, MTK, Sierra Wireless, QC
* Further analysis on suitability based on simulation
	+ Ericsson

The following can be observed from simulations of companies:

* With the same resources and TBS, QPSK without repetition is better than 16QAM with 2 repetitions with 1.3dB~3dB gap. [2][5][8]
* With 16QAM with 2 repetitions, the data rate can be increased by 20%~50% compared with QPSK for some SNR level. [3]
* Only the largest TBS entries may be the use-case for 16QAM with 2 repetitions. [9]
* For 16QAM with 2 repetitions, for the largest TBS entries the required SINR is in the range from ⁓ 6.45 dB to ⁓ 10.43 dB, under which 16QAM without repetition can be used. [9]

Based on the inputs, the following is proposed:

Proposal 5.1: Down-selection on whether repetition of 2 is supported for 16-QAM in downlink.

Please input your further comments for the down-selection:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | Based on the simulation result, we can see the benefit of repetition even with 16QAM. If we have extra-states/fields in DCI to indicate the 16QAM&Repetition number, we can consider to support. |
| Ericsson | We are not supportive of using 2 repetitions for 16-QAM in DL until the required sinr range for the use-case(s) has been analyzed as to determine its suitability. Moreover, we also need to discuss the potential impacts on the channel quality reporting if the 2 repetitions case for 16-QAM were supported. |
| MTK | We insist repetition of 2 is unnecessary for 16QAM in downlink. Regarding one of above observations “With 16QAM with 2 repetitions, the data rate can be increased by 20%~50% compared with QPSK for some SNR level. [3]”, the benefit is data rate increase, however if it compares with 16QAM without repetition, the benefit maybe disappear or be negligible. |
| Huawei, HiSilicon | Support to not use 2 repetitions |
| Nokia, NSB | We are fine with the proposal. As discussed earlier, we’d like the gNB to have the option to schedule 16-QAM DL with repetition of 2 to potentially improve data rate. |
| Qualcomm | We would prefer to not support 2 repetitions. |
| ZTE,sanechips | Support 2 repetitions. The reason we support 2 repetition is that Data rate of 16QAM with 2 repetition will be larger than that of QPSK with 1 repetition, under the same occupied resources. |
| FL summary | No clear majority view, propose to discuss online for down-selection. |

## Support of 16QAM for NB-IoT uplink

### Issue 4: The TBS table.

There are following proposals on TBS design of 16-QAM for UL unicast

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | **Proposal 5: Confirm the working assumption below to support 16-QAM in UL.****The following TBS indices are introduced for uplink**

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 |  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2536 |  |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 |  |  |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 |  |  |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2536 |  |  |
| 20 | 440 | 904 | 1384 | 1864 | 2344 |  |  |  |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 |  |  |  |

 |
| [3] | **Proposal 13: Confirm the following working assumptions from RAN1#103-e –*** **The following TBS indices are introduced for uplink**

|  |  |
| --- | --- |
| **I\_TBS** | **I\_RU** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | [2472, 2536] |  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | [2536] |  |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 |  |  |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 |  |  |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | [2536] |  |  |
| 20 | 440 | 904 | 1384 | 1864 | 2344 |  |  |  |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 |  |  |  |

**Proposal 14: For uplink, select the following TBS values –*** **I\_TBS=15, I\_RU=6 : TBS=2472**
* **I\_TBS=16, I\_RU=6 : TBS=2536**
* **I\_TBS=19, I\_RU=5 : TBS=2536**
 |
| [4] | Table 6: Extended TBS for UL 16QAM

|  |  |
| --- | --- |
| **I\_TBS** | **I\_RU** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 |  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2536 |  |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 |  |  |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 |  |  |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2536 |  |  |
| 20 | 440 | 904 | 1384 | 1864 | 2344 |  |  |  |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 |  |  |  |

 |
| [8] | **Proposal 15: Confirm the WA on the NPUSCH TBS table, with the following changes:*** **[2536] is replaced by 2536**
* **[2472, 2536] is replaced by 2472**
 |
| [9] | **Observation 5 Based on simulation results the Working Assumption for UL can be confirmed supporting a 12-subcarrier allocation using 16-QAM for NPUSCH Format 1.****Proposal 15 Confirm the Working Assumption for UL** **to support a 12-subcarrier allocation using 16-QAM for NPUSCH Format 1.** |
| [12] | Observation 4 Based on simulation results the Working Assumption for UL can be confirmed supporting a 12-subcarrier allocation using 16-QAM for NPUSCH Format 1 |

#### Round-1 proposals and discussion

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

**Proposal 7: Confirm the following working assumption:**

* The following TBS indices are introduced for uplink

|  |  |
| --- | --- |
| **I\_TBS** | **I\_RU** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 |  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2536 |  |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 |  |  |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 |  |  |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2536 |  |  |
| 20 | 440 | 904 | 1384 | 1864 | 2344 |  |  |  |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 |  |  |  |

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support proposal 7 |
| Ericsson | We are fine. I just want to point out that the TBS/MCS table for UL will make possible to transmit the max Rel-16 TBS with half of the time-domain resources when 16-QAM is used (i.e., TBS = 2536 bits with I\_RU = 4), which is an ability that DL should also have. |
| Nokia, NSB | We support proposal 7 |
| Qualcomm | Support proposal 7. |
| Huawei, HiSilicon | Support proposal 7 |
| MTK | Support proposal7 |
| ZTE,sanechips | Support proposal 7. |

The following agreement has been achieved:

**Agreement**

Confirm the following working assumption:

* The following TBS indices are introduced for uplink

|  |  |
| --- | --- |
| **I\_TBS** | **I\_RU** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 |  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2536 |  |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 |  |  |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 |  |  |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2536 |  |  |
| 20 | 440 | 904 | 1384 | 1864 | 2344 |  |  |  |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 |  |  |  |

### Issue 5: The breaking point from QPSK to 16QAM.

There are following proposals on TBS design of 16-QAM for UL unicast

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 6: The UL TBS entries between 13 (TBS of 2536 for ISF = 7) and 21 are used for 16QAM.****Figure 6. NPUSCH BLER of ITBS=12, 13 QPSK vs. 16QAM with 1T2R and Isf = 4 in AWGN****Figure 7. NPUSCH BLER of ITBS=12, 13 QPSK vs. 16QAM with 1T2R and Isf = 1 in AWGN** |
| [3] | **Proposal 15: The downlink TBS entries between 14 and 21 are used for 16-QAM.**Figure 2. NPDSCH performance with 16-QAM. |
| [4] | ***Observation 4: For NPUSCH with 12 subcarriers, 16QAM performance is significantly better than QPSK performance at TBS 13 (2536 bits with IRU=7).******Proposal 10: For NPUSCH, 16QAM can be used for TBS indexes from 13 to 21.***Figure 4 BLER performance for NPUSCH with 1T2R |
| [9] | **Proposal 16 The TBS/MCS Table for 16-QAM in UL to support a 12-subcarrier allocation uses as breaking point ITBS = 13 as last ITBS index for QPSK and ITBS = 14 as first ITBS index for16-QAM.** **Proposal 17 In line with the Working Assumption for UL, the TBS/MCS Table to support a 12-subcarrier allocation using 16-QAM with NPUSCH Format 1 is as follows:**

|  |  |  |
| --- | --- | --- |
| **.Modulation Scheme** |  | **Number of RUs** |
| **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 | 1000 |
| 7 | 104 | 224 | 328 | 472 | 584 | 712 | 1000 | 1224 |
| 8 | 120 | 256 | 392 | 536 | 680 | 808 | 1096  | 1384  |
| 9 | 136 | 296 | 456 | 616 | 776 | 936 | 1256  | 1544  |
| 10 | 144 | 328 | 504 | 680 | 872 | 1000 | 1384  | 1736  |
| 11 | 176 | 376 | 584 | 776 | 1000 | 1192 | 1608  | 2024  |
| 12 | 208 | 440 | 680 | 1000 | 1128 | 1352  | 1800  | 2280  |
| 13 | 224  | 488  | 744  | 1032 | 1256  | 1544  | 2024  | 2536  |
| 16-QAM only | 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | -  |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2536 | - |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | - | - |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 | - | - |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2536 | - | - |
| 20 | 440 | 904 | 1384 | 1864 | 2344 | - | - | - |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 | - | - | - |

**Figure 3: 10% BLER for all TBS entries intended to be used for 16-QAM in UL with a 12 subcarriers allocation (i.e., Full PRB allocation).*** ITBS14\_16QAMavg-to-ITBS13\_QPSKavg = abs(3.54 dB – 3.69 dB) ⁓ 0.15 dB.

where:ITBS14\_16QAMavg and ITBS13\_QPSKavg refer to the average SINR across all the TBS entries in the rows associated to ITBS 14 for 16-QAM and ITBS 13 for QPSK respectively.The resulting average SINR difference between ITBS = 13 which uses QPSK and ITBS = 14 which uses 16-QAM resulted to be smaller than 1 dB (⁓ 0.15 dB), hence is suitable to have as breaking point ITBS = 13 as last ITBS index for QPSK and ITBS = 14 as first ITBS index for16-QAM. |

#### Round-1 proposals and discussion

On breaking points for NPUSCH, there are following proposals:

* The UL TBS entries between 13 and 21 are used for 16QAM.
	+ Huawei, HiSilicon, ZTE
* The UL TBS entries between 14 and 21 are used for 16QAM.
	+ Nokia, NSB, Ericsson

Based on the inputs, the following is proposed:

**Proposal 8: On the breaking point between QPSK and 16QAM for NPUSCH, down-select between the following options:**

* **Option 1: The UL TBS entries between 13 and 21 are used for 16QAM.**
* **Option 2: The UL TBS entries between 14 and 21 are used for 16QAM.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support the proposal, our preference is option 2. |
| Ericsson | We support Option 2, under the understanding that proposal 8 option 2 means in terms of breaking-point that I\_TBS = 13 is the last I\_TBS index used for QPSK and I\_TBS = 14 is the first I\_TBS index used for 16-QAM. |
| Nokia, NSB | We are fine with the proposal and support Option 2. In our analysis, using QPSK for I\_TBS = 13 would result in better performance and also maintain the same MCS selection as legacy. |
| Huawei, HiSilicon | Support the proposal and prefer option 1. |
| MTK | Support and prefer option2. |
| ZTE,sanechips | OK with Proposal 8. We prefer Option1. For NPUSCH with 12 subcarriers, 16QAM performance is significantly better than QPSK performance at TBS 13 in fading channel. |

#### Round-2 proposals and discussion

On breaking points for NPUSCH, there are following proposals based on comments:

* The UL TBS entries between 13 and 21 are used for 16QAM.
	+ Huawei, HiSilicon, ZTE
* The UL TBS entries between 14 and 21 are used for 16QAM.
	+ Nokia, NSB, Ericsson, Lenovo, Moto, MTK

The following can be observed from simulations:

|  |  |  |  |
| --- | --- | --- | --- |
| TBS indexes | 12 | 13 | 14 |
| [2] | 16QAM < QPSK (0.5dB gap) | 16QAM > QPSK (0.2~0.4dB gap) |  |
| [3] | 16QAM < QPSK for NPDSCH | 16QAM < QPSK for NPDSCH |  |
| [4] | 16QAM has almost the same performance with QPSK  | 16QAM > QPSK (1dB gap) |  |
| [9] |  |  | Average SINR difference between ITBS = 13 QPSK and ITBS = 14 is smaller than 1 dB (⁓ 0.15 dB) |

Therefore, the following is proposed for down-selection:

**Proposal 8.1: On the breaking point between QPSK and 16QAM for NPUSCH, down-select between the following options:**

* **Option 1: The UL TBS entries between 13 and 21 are used for 16QAM.**
* **Option 2: The UL TBS entries between 14 and 21 are used for 16QAM.**

Please input your further comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | We don’t have strong view. We slightly prefer Option 2 with 8 TBS entries for potential DCI design. |
| Ericsson | We support Option 2. |
| MTK | Prefer to Opiton2 |
| Huawei, HiSilicon | Support the proposal and prefer option 1. |
| Nokia, NSB | We are fine with the proposal. We support Option 2. In our analysis, using QPSK for I\_TBS = 13 would result in better performance and also maintain the same MCS selection as legacy. |
| ZTE,sanechips | We support option1. It should be concluded based on the fading channel. |
| FL summary | Based on majority view, the following is proposed:**The UL TBS entries between 14 and 21 are used for 16QAM.** |

### Issue 6: Applicability

The following are proposed on scheduling of TBS and modulation:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 7: 16-QAM can be used for NPUSCH with multi-tone 3 and 6 subcarriers.** |
| [3] | **Proposal 16: Repetitions are not supported for 16-QAM in the uplink.****Proposal 19: 16-QAM is not supported for sub-PRB allocation.** |
| [4] | ***Proposal 9: UL 16QAM should be supported for 3/6 subcarriers allocation.*** |
| [6] | ***Proposal 6: At least large number of repetitions should not be considered in 16-QAM in NPUSCH.******Proposal 7: Muli-tone allocation with 3 or 6 subcarrier should be supported for 16QAM NPUSCH.*** |
| [7] | Proposal 3: 3 and 6 subcarriers are not supported with 16QAM. |
| [8] | **Proposal 13: UL 16-QAM is applicable for NPUSCH scheduled from a DCI with CRC scrambled by C-RNTI.*** **At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.**
* **FFS: Applicability of 16-QAM for PUR or EDT.**

**Proposal 14: UL 16-QAM is applicable at least to NPUSCH with full-PRB allocations only and single repetition.** |
| [9] | **Observation 6 Although 16-QAM requires a high SNR and resource allocations < 12 subcarriers are mainly targeted towards low SNR regimes (especially single-tone allocations), still there are scenarios (e.g., NPRACH and NPUSCH coexistence) where multi-tone allocations could benefit from a higher order modulation.** **Observation 7 Based on simulation results the Working Assumption for UL can be confirmed supporting a 6-subcarrier allocation using 16-QAM for NPUSCH Format 1.****Proposal 18 Confirm the Working Assumption for UL to support a 6-subcarrier allocation using 16-QAM for NPUSCH Format 1.****Proposal 19 The TBS/MCS Table and breaking point used to support a 12-subcarrier allocation is also used to support a 6-subcarrier allocation using 16-QAM with NPUSCH Format 1.****Observation 8 Based on simulation results the Working Assumption for UL can be confirmed supporting a 3-subcarrier allocation using 16-QAM for NPUSCH Format 1.****Proposal 20 Confirm the Working Assumption for UL to support a 3-subcarrier allocation using 16-QAM for NPUSCH Format 1.****Proposal 21 The TBS/MCS Table and breaking point used to support a 12-subcarrier allocation is also used to support a 3-subcarrier allocation using 16-QAM with NPUSCH Format 1.** |
| [12] | **Observation 5 Based on simulation results the Working Assumption for UL can be confirmed supporting a 6-subcarrier allocation using 16-QAM for NPUSCH Format 1****Observation 6 Based on simulation results the Working Assumption for UL can be confirmed supporting a 3-subcarrier allocation using 16-QAM for NPUSCH Format 1** |

#### Round-1 proposals and discussion

On whether 16-QAM can be used for 3 and 6 subcarriers, there are following proposals:

* 16-QAM can be used for 3 and 6 subcarriers NPUSCH
	+ Huawei, HiSilicon, ZTE, Lenovo, Moto, Ericsson
* 16-QAM cannot be used for 3 and 6 subcarriers NPUSCH
	+ Nokia, NSB, Sierra Wireless, QC

Based on the inputs, the following is proposed:

**Proposal 9: Down-select between the following options:**

* **Option 1: 16-QAM can be used for 3 and 6 subcarriers NPUSCH**
* **Option 2: 16-QAM cannot be used for 3 and 6 subcarriers NPUSCH**

There are proposals that repetition or at least large number of repetitions are not used for 16-QAM. Therefore, the following is proposed:

**Proposal 10: Repetition is not used for 16-QAM in uplink.**

There are proposals that application of 16-QAM related DCI, therefore, the following is proposed:

**Proposal 11: UL 16-QAM is applicable for NPUSCH scheduled from a DCI with CRC scrambled by C-RNTI.**

* **At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.**
* **FFS: Applicability of 16-QAM for PUR or EDT.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support proposal 9. Our preference is option 1 due to the higher spectrum efficiency and potential resource multiplexing with legacy 3/6 tone uplink scheduling.For proposal 10, we need further study (e.g., further evaluation performance)Support proposal 11. |
| Ericsson | On proposal 9:We support Option 1, we suggest to state “NPUSCH Format 1” rather than just “NPUSCH”.On proposal 10:We are ok since there is no analysis or evaluation we can refer as to support it.On proposal 11:We are ok with it. |
| Nokia, NSB | We are fine with the three proposals.For proposal 10, our analysis shows that QPSK performs than 16-QAM with repetition. Since there is no increase in TBS, there is no possible increase in data rate using 16-QAM with repetition. Therefore we support proposal 10.We are fine with proposal 11. However, at least for EDT we don’t see the need to support 16-QAM so we would be OK to remove EDT from the FFS. |
| Qualcomm | Support all proposals.  |
| Huawei, HiSilicon | We support option 1 of proposal 9 due to the advantages of achieving higher data rate and scheduling flexibility for 16QAM. We support proposal 10 and proposal 11. |
| MTK | We support proposal10/11 and proposl9 with option1. |
| ZTE,sanechips | Support all proposals.For Proposal 9, 16-QAM can be used for 3 and 6 subcarriers NPUSCH because,* 3/6 subcarriers allocation is also used for flexible sub-PRB based scheduling. If 16QAM is not supported for 3/6 subcarriers NPUSCH, the scheduling of 16QAM capability UEs will be restricted.
* PAPR is not the main issue when 3/6 subcarriers allocation is used for flexible sub-PRB based scheduling.
* 16QAM can also be supported to improve peak data rate for 3/6 subcarriers allocation.
 |

The following has been achieved:

**Agreement**

Repetition is not used for 16-QAM in uplink.

**Agreement**

UL 16-QAM is applicable for NPUSCH scheduled from a DCI with CRC scrambled by C-RNTI.

* At least C-RNTI from USS is supported, FFS if 16-QAM is applied to C-RNTI from CSS.
* FFS: Applicability of 16-QAM for PUR or EDT.

#### Round-2 proposals and discussion

On whether 16-QAM can be used for 3 and 6 subcarriers, there are following proposals:

* 16-QAM can be used for 3 and 6 subcarriers NPUSCH
	+ Huawei, HiSilicon, ZTE, Lenovo, Moto, Ericsson, MTK
* 16-QAM cannot be used for 3 and 6 subcarriers NPUSCH
	+ Nokia, NSB, Sierra Wireless, QC

Based on the inputs, the following is proposed:

**Proposal 9.1: Down-select between the following options:**

* **Option 1: 16-QAM can be used for 3 and 6 subcarriers NPUSCH format 1**
* **Option 2: 16-QAM cannot be used for 3 and 6 subcarriers NPUSCH format 1**

Please input your further comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | We support option 1. Consider the resource multiplexing with legacy NPUSCH format 1 (with 3 or 6 tones) and NPUSCH format 2. |
| Ericsson | We support option 1. |
| MTK | We prefer Option1 |
| Huawei, HiSilicon | Support option 1. If 3 and 6 subcarriers are not supported, then 16QAM scheduling would be much limited. And supporting 3/6 tones can also improve the date rate. |
| Nokia, NSB | We are fine with the proposal. We support Option 2. |
| ZTE,sanechips | Option1 is preferred. |
| FL summary | Based on the majority view, the following is proposed:**16-QAM can be used for 3 and 6 subcarriers NPUSCH format 1** |

## DCI

### Issue 7: DCI design.

There are following proposals on power allocation

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Proposal 8: The introduction of 16-QAM should avoid increase of DCI size.**Proposal 9: Considering possible channel condition variations, the flexibility of scheduling Rel-16 QPSK TBS and repetition numbers is supported if 16QAM is enabled.** |
| [3] | **Proposal 6: The DCI N1 size is not increased for 16-QAM support.****Proposal 7: For 16-QAM support in the downlink DCI N1, the MCS field is increased to 5 bits, and repetition field is decreased to 1 bit.****Proposal 17: The DCI N0 size is not increased for 16-QAM support.****Proposal 18: For 16-QAM support in the uplink DCI N0, the MCS field is increased to 5 bits, and repetition field is not used.** |
| [4] | ***Proposal 5: If 4-bit MCS table is adopted for DL 16QAM for guard-band and standalone deployment, it should be considered to remove the existing 6 MCS entries and add new 8 MCS entries.******Proposal 6: If 5-bit MCS table is adopted for DL 16QAM, for guard-band and standalone deployments,**** ***MCS 0~13 correspond to TBS 0~13 with QPSK modulation***
* ***MCS 14~23 correspond to TBS 12~21 with 16QAM modulation***
* ***The most significant bit of ‘repetition number’ field can be repurposed to indicate MCS***

***Proposal 7: If 5-bit MCS table is adopted for DL 16QAM, for in-band deployment,**** ***MCS 0~10 correspond to TBS 0~10 with QPSK modulation***
* ***MCS 11~18 correspond to TBS 10~17 with 16QAM modulation***

***Proposal 11: 5-bit MCS table can be defined for UL 16QAM for NB-IoT.**** ***MCS 0~13 correspond to TBS 0~13 with QPSK***
* ***MCS 14~22 correspond to TBS 13~21 with 16QAM***
 |
| [5] | **Proposal1：The size of the MCS field in DCI N1/N0 in UE-specific search space is increased to 5 bits.** |
| [6] | ***Proposal 4: For the DCI optimization, the joint coding of MCS and repetition number field can be considered.******Proposal 8: For the DCI optimization based on the existing agreement, the joint coding of MCS, Repetition number and Resource assignment field can be considered.*** |
| [8] | **Proposal 6: Do not introduce additional DCI bits to support 16-QAM. Introduce two new 4-bit MCS tables (16-QAM in-band and 16-QAM standalone).****Proposal 7: If the “repetition number” field in DCI indicates 1 repetition, the MCS field indicates an entry in the 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.****Proposal 11: RAN1 to discuss whether to introduce one or more “implicit MCS” for retransmissions in the MCS table for UL 16-QAM.** |
|  |  |

#### Round-1 proposals and discussion

The proposed schemes are diverse, and several companies proposed the principle that the DCI size is not increased to support 16-QAM. Therefore, the following is proposed:

Proposal 12: The DCI size is not increased to support 16-QAM in uplink and downlink.

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support proposal 12 |
| Ericsson | We need to settle and agree first on the TBS/MCS tables, and then we can come back to start discussing DCI design aspects. |
| Nokia, NSB | We are fine the proposal but it may be better to first discuss whether all existing legacy MCS + repetition values need to be supported for UE configured with 16-QAM.  |
| Qualcomm | We should first decide on what features apply (e.g. repetitions / no repetitions), and then we can decide on this.If no repetitions are supported, we think this should be achievable. |
| Huawei, HiSilicon | Support proposal 12 |
| MTK | It’ better to make decision after having an agreement on the MCS bits field and repetition field. |
| ZTE,sanechips | Support proposal 12. |

## Downlink power allocation to support 16QAM

### Issue 8: Power allocation.

There are following proposals on power allocation

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 10: Explicit signaling of power ratios of NPDSCH EPRE to NRS EPRE for the following cases is supported. If all these parameters are the same or the NPDSCH EPRE in all symbols are the same, then only one parameter is needed for signaling.** * **NPDSCH in symbols without NRS and CRS**
* **NPDSCH in symbols with CRS (only for “In-band” deployment)**
* **NPDSCH in symbols with NRS**
 |
| [3] | **Proposal 10: NPDSCH EPRE in symbols with NRS can be different than NPDSCH EPRE in symbols without NRS and CRS.****Proposal 11: The total transmit power across OFDM symbols should be constant.****Proposal 12: The UE-specific power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS (**$ρ\_{C}$**) is explicitly ignaled. The other two power ratio values can be determined by the UE.**  |
| [4] | ***Observation 5: In practice, different transmit power configured between OFDM symbols may cause phase diversion.******Observation 6: The transmit power between different OFDM symbols is constant in R16 NB-IoT when a given NRS power is configured.******Proposal 12: The same total transmit power is set for each OFDM symbol for Rel-17 NB-IoT DL power allocation.******Proposal 13: A new UE-specific higher layer parameter is introduced to indicate the ratio of NPDSCH EPRE and NRS EPRE in symbols with NRS.******Proposal 14: For in-band deployment, the ratio of NRS EPRE to CRS EPRE is indicated for both same PCI and different PCI.*** |
| [6] | ***Proposal 5: Network should semi-statically configure three types of NPDSCH EPRE separately.*** |
| [8] | **Observation 1: In NB-IoT, the power level change of NPDSCH relative to NRS does not have impact on legacy NPDSCH with QPSK. This does not hold anymore with 16-QAM NPDSCH.****Proposal 9: RAN1 to decide among the following alternatives:*** **Alt1: Rel-16 NRS power levels are kept (**$ρ\_{A}=ρ\_{C}$**).**
* **Alt2: An additional “power boost” value for NRS is introduced (**$ρ\_{A}\ne ρ\_{C}$**).**

**Proposal 10: The UE derives the values of** $ρ\_{A}$**,** $ρ\_{B}$**,** $ρ\_{C}$ **implicitly based on*** **Power boost value for NRS (if introduced)**
* **NRS and CRS relative power level.**
* **Number of NRS and CRS ports.**
 |
| [9] | **Propsoal 11 For Stand-alone and Guard-band deployments, the power ratios of NPDSCH EPRE to NRS EPRE are as in LTE defined in terms of the following types:****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]****Where:****ρ\_a = PA [dB]****PB is an index that refers to the linear ratio between ρ\_b and ρ\_a (i.e.,**${10^{\left(\frac{ρ\\_b}{10}\right)}}/{10^{\left(\frac{ρ\\_a}{10}\right)}}$**)****Proposal 12 For In-band deployments, the power ratios of NPDSCH EPRE to NRS EPRE are as in LTE defined in terms of the following types:****Type A, NPDSCH in symbols without NRS and CRS: NPDSCH EPRE = NRS EPRE + ρ\_a [dB]****Type B, NPDSCH in symbols with NRS: NPDSCH EPRE = NRS EPRE + ρ\_b [dB]****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 13 Explicit signaling of the power ratios NPDSCH EPRE to NRS EPRE is used as follows:****Type A, NPDSCH in symbols without NRS and CRS: PA is configured as UE specific****Type B, NPDSCH in symbols with NRS: PB is configured as cell specific.****Type C, NPDSCH in symbols with CRS (only for “In-band” deployment): PC is configured as cell specific.****RAN2 to decide the messages used to carry the UE specific (e.g., Msg4) and cell specific signalling (e.g., Msg4 and SIB22-NB).** |

#### Round-1 proposals and discussion

There are following options proposed for power allocation:

* Explicit signaling of power ratios for the three cases
	+ Huawei, HiSilicon, Lenovo, Moto, Ericsson
* The power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS is signaled, and the others are determined by the UE assuming the same power between symbols.
	+ Nokia, NSB, ZTE,
* The power ratios of the three cases are determined by NRS power boost (if supported), power offset between NRS and CRS, and number of NRS and CRS ports, assuming the same power between symbols
	+ QC

Where the three cases include the power ratios between NPDSCH EPRE to NRS EPRE for the following cases:

* NPDSCH in symbols without NRS and CRS
* NPDSCH in symbols with CRS (only for “In-band” deployment)
* NPDSCH in symbols with NRS

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

Proposal 13: Down-select between the following options on the signal of ratios of NPDSCH EPRE to NRS EPRE for the three cases: NPDSCH in symbols without NRS and CRS, NPDSCH in symbols with CRS (only for “In-band” deployment) and NPDSCH in symbols with NRS.

* **Option 1: Explicit signaling of the power ratios for the three cases**
* **Option 2: The power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS is signaled, and the others are determined by the UE assuming the same power between symbols.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support the proposal 13, our preference is option 2. We should assume that all symbol with same power. |
| Ericsson | From the contributions submitted to RAN1 #104-e, it seems that there are two main alternatives “$ρ\_{A}\ne ρ\_{C}$” and “$ρ\_{A}=ρ\_{C}$”, and yet within them there are sub-alternatives for the in-band case accounting for whether the PCI is different or the same. I will try to summarize it below. Assuming the following terminology and LTE’s as design baseline:$ρ\_{A}$: Applicable to NPDSCH in symbols with NRS.$ρ\_{B}$: Applicable to NPDSCH in symbols with CRS (required for in-band NB-IoT only).$ρ\_{C}$: Applicable to NPDSCH in symbols without NRS and CRS.From the submitted contributions to RAN1 #104-e, the DL Power Allocation can consider the following alternatives:* Alt1: $ρ\_{A}\ne ρ\_{C}$
	+ Alt-1a: “$ρ\_{C}$” is UE-specific signaled and the index “PA“ referring to a linear power ratio between “$ρ\_{A}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{A}$”, in addition, for in-band deployments in the case of a same PCI “*nrs-CRS-PowerOffset*” is used to implicitly obtain “$ρ\_{B}$”, otherwise (i.e., when different PCI) the index “PB“ referring to a linear power ratio between “$ρ\_{B}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{B}$”.
	+ Alt-1b: “$ρ\_{C}$” is UE-specific signaled and the index “PA“ referring to a linear power ratio between “$ρ\_{A}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{A}$”, in addition, for in-band deployments regardless of whether the PCI is the same or different the index “PB“ referring to a linear power ratio between “$ρ\_{B}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{B}$”.
	+ Alt-1c: “$ρ\_{C}$” is UE-specific signaled and the index “PA“ referring to a linear power ratio between “$ρ\_{A}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{A}$”, in addition, for in-band deployments regardless of whether the PCI is the same or different “$ρ\_{B}$” is determined from the parameter “*nrs-CRS-PowerOffset*” (i.e., signaling is added for the different PCI case).
* Alt2:  $ρ\_{A}=ρ\_{C}$)
	+ Alt-2a: Assuming the EPRE ratio between NRS and NPDSCH is fixed to 0dB for single port, and 3dB for dual port (i.e., the EPRE of NPDSCH is constant across symbols), then “$ρ\_{A}$” and “$ρ\_{C}$” are not required to be signaled, for in-band deployments in the case of a same PCI “*nrs-CRS-PowerOffset*” is used to implicitly obtain “$ρ\_{B}$”, otherwise (i.e., when different PCI) the index “PB“ referring to a linear power ratio between “$ρ\_{B}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{B}$”.
	+ Alt-2b: Assuming the EPRE ratio between NRS and NPDSCH is fixed to 0dB for single port, and 3dB for dual port (i.e., the EPRE of NPDSCH is constant across symbols), then “$ρ\_{A}$” and “$ρ\_{C}$” are not required to be signaled, for in-band deployments regardless of whether the PCI is the same or different the index “PB“ referring to a linear power ratio between “$ρ\_{B}$” and “$ρ\_{C}$” is cell-specific signaled as to obtain “$ρ\_{B}$”.
	+ Alt-2c: Assuming the EPRE ratio between NRS and NPDSCH is fixed to 0dB for single port, and 3dB for dual port (i.e., the EPRE of NPDSCH is constant across symbols), then “$ρ\_{A}$” and “$ρ\_{C}$” are not required to be signaled, for in-band deployments regardless of whether the PCI is the same or different “$ρ\_{B}$” is determined from the parameter “*nrs-CRS-PowerOffset*” (i.e., signaling is added for the different PCI case).

It seems that we need to discuss the aspects above as to be able to reach a clear agreement. |
| Nokia, NSB | We are fine with the proposal. Our preference is Option 2. |
| Qualcomm | We agree with Ericsson that we should discuss first rho\_a / rho\_c. In either case, we do not see the need to indicate explicitly all power offsets (i.e., if we allow rho\_a not equal to rho\_c, we would support Option 2). |
| Huawei, HiSilicon | Support this proposal. For whether rho\_a is equal to rho\_c or not, we think it depends on the eNB configuration. |
| ZTE,sanechips | We are fine with the proposal. Option 2 is preferred since it can achieve UE-specific DL power allocation and has lower complexity. |

#### Round-2 proposals and discussion

There were comments that firstly we should firstly decide whether the NPDSCH EPRE in symbols with NRS equals or not to that in symbols without NRS and CRS. It seems most companies has presumed that they can be different, i.e., NRS power boost is supported. Therefore, the following is proposed:

**Proposal 13.1: The NPDSCH EPRE in symbols with NRS can be different with the NPDSCH EPRE in symbols without CRS and NRS.**

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | Do you mean “the following NPDSCH EPRE ρ\_a and ρ\_c are separately indicated or derived”* ρ\_a: *NPDSCH EPRE in symbols without NRS and CRS*
* ρ\_b: *NPDSCH in symbols with CRS (only for “In-band” deployment)*
* ρ\_c: *NPDSCH in symbols with NRS*
 |
| Ericsson | In our understanding it is being proposed that $ρ\_{A}\ne ρ\_{C}$. In our view is worth discussing the pros and cons between “$ρ\_{A}\ne ρ\_{C}$” and “$ρ\_{A}=ρ\_{C}$”. Moreover, the proposal should state somewhere FFS on signaling details, and there should be another FFS for the handling on whether the PCI is different or the same. |
| Huawei, HiSilicon | It depends on eNB configuration. If no NRS power boost, then it is the same. We suggest the following revisions.**The NPDSCH EPRE in symbols with NRS can be different with the NPDSCH EPRE in symbols without CRS and NRS.****Note: it does not preclude the same NPDSCH EPRE between symbols with NRS, and symbols without CRS and NRS.** |
| Nokia, NSB | We support the proposal. We think it is already clear from the proposal that the NPDSCH EPRE in symbols with NRS can also be the same as NPDSCH EPRE in symbols without CRS and NRS. |
| ZTE,sanechips | We also think the NPDSCH EPRE in symbols with NRS can also be the same as NPDSCH EPRE in symbols without CRS and NRS. |
| FL summary | Based on the comments, the following revision is proposed:**The NPDSCH EPRE in symbols with NRS can be different and can be the same with the NPDSCH EPRE in symbols without CRS and NRS.*** **FFS on signaling details**
* **FFS for the handling on whether the PCI is different or the same**
 |

## Soft buffer size

### Issue 9: Soft buffer size.

There are following proposals on power allocation

|  |  |
| --- | --- |
| Sourcing | proposals |
| [3] | **Proposal 4: The soft buffer size is doubled with respect to QPSK, i.e. to 12800 bits.** |
| [4] | ***Proposal 15: DL soft buffer size of 12800 bits is specified for NB-IoT 16QAM.*** |
| [8] | **Proposal 5: Do not introduce LBRM for 16-QAM. The soft buffer size is doubled with respect to QPSK.** |
| [9] | **Proposal 14 For the support of 16-QAM in DL, the total number of soft channel bits is doubled with respect to what is today in TS 36.306 Table 4.1C-1 for a Category NB2 UE. That is, 12800 is the total number of channel bits for a Category NB2 UE supporting 16-QAM in DL.** |

#### Round-1 proposals and discussion

Based on the input, the following is proposed:

Proposal 14: The soft buffer size for 16QAM is 12800 bits.

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support proposal 14 |
| Ericsson | We are ok |
| Nokia, NSB | We support FL’s proposal |
| Qualcomm | Agree |
| Huawei, HiSilicon | Support proposal 14, it should be clarified that it is for NB2 UE supporting 16QAM. |
| MTK | Support porposal14. |
| ZTE,sanechips | OK |

The following has been achieved:

**Agreement**

The soft buffer size for Cat. NB2 UEs supporting 16QAM for downlink is 12800 bits.

## Channel quality reporting

### Issue 10: Channel quality reporting

There are following proposals on power allocation

|  |  |
| --- | --- |
| Sourcing | proposals |
| [3] | **Proposal 8: 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 9: Reuse Msg3 and MAC CE downlink channel quality measurement report defined in 36.133 for 16-QAM CQI reporting. FFS details.** |
| [5] | **Proposal2: Introduce Layer1 CQI report method by utilizing spare index of MCS field (5 bits) in DCI N0.** |
| [9] | **Proposal 9 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.****Proposal 10 The three unused entries in the legacy CQI mapping Table in clause 9.1.22.15 of TS 36.213 (i.e., Table 9.1.22.15-1) are used for the CQI reporting of 16-QAM in DL.*** **The NPDCCH and NPDSCH repetition level is equal to 1.**
	+ **candidateRep-M is reported when the SINR is suitable for 16-QAM with ITBS =A/D.**
		- **FFS: A for stand-alone and guard-band deployments, and D for in-band deployments.**
	+ **candidateRep-N is reported when the SINR is suitable for 16-QAM with ITBS =B/E.**
		- **FFS: B for stand-alone and guard-band deployments, and E for in-band deployments.**
	+ **candidateRep-O is reported when the SINR is suitable for 16-QAM with ITBS =C/F.**
		- **FFS: C for stand-alone and guard-band deployments, and F for in-band deployments.**
 |
| [10] | ***Observation 1: For DL 16QAM, the channel quality report should indicate NPDSCH channel state differentiated from the number of NPDCCH repetitions.******Proposal 1: The CQI table can contain QPSK and 16QAM modulation schemes covering from low spectral efficiency to high spectral efficiency to meet different channel state requirements.**** ***CQI table is defined based on DL 16QAM MCS table***

***Proposal 2: CQI report can only be supported in connected mode for NB-IoT 16QAM.******Proposal 3: Measurement reference resource may not be specified for CQI report for NB-IoT 16QAM.*** |
| [11] | **Observation 1:** **In current NB-IoT, the channel quality reporting in Msg3 and** **connected mode are NPDCCH repetition level reports.****Observation 2:** **For UE in good coverage and hence not needing repetition, the repetition-level based channel quality reporting does not convey sufficiently fine-grained channel quality information.** **Proposal 1: Finer NB-IoT channel quality reporting is supported to provide sufficient channel quality information in good coverage, particularly for 16-QAM.****Proposal 2: Re-purpose the channel quality reporting field in Msg3 and MAC CE to support finer channel quality reporting.** |

#### Round-1proposals and discussion

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 15: If 16-QAM is configured for NPDSCH, the channel quality report is for the NPDSCH channel state.

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo&MotoM | Support proposal 15. |
| Ericsson | We would prefer to sort out first the number of supported repetitions before start discussing channel quality reporting. |
| Nokia, NSB | We need further clarification on the proposal. Our view is that we would reuse existing channel quality report and add new values relevant for 16-QAM. The existing values would still be based on NPDCCH while the new values would be based on NPDSCH. |
| Qualcomm | This objective is RAN2-led. We suggest not discussing this for now (note that, in previous releases, we discussed similar issues and ended up with 0 RAN1 impact) |
| Huawei, HiSilicon | Support proposal 15. We think the detailed signaling is up to RAN2, but RAN1 needs to decide e.g. the metrics for channel quality report. |
| MTK | Support proposal15.As stated in [5], we have opportunity to further enhance the CQI report performance than R16, this relates to L1 DCI impact and should be considered with MCS bits field settling. |
| ZTE,sanechips | Agree with Qualcomm’s view. Channel quality report for the NPDSCH can be discussed later. |

## Others

**Issue 11: Others**

There are also other proposals as below:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [3] | **Proposal 20: 16-QAM can be supported together with DL/UL multi-TB scheduling in unicast.****Proposal 21: 16-QAM can be supported together with PUR.****Proposal 22: 16-QAM is not supported for EDT.** |
| [8] | **Proposal 12: RAN1 to consider adding an additional power control parameter to allow for increased power with 16-QAM (e.g. similar to** $Δ\_{TF}$**)** |

Please input your comments if you think any proposed 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. R1-2100253 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2100507 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
4. R1-2100567 Discussion on UL and DL 16QAM for NB-IoT ZTE
5. R1-2100581 Consideration on CQI report and Repetition applicability for 16QAM in R17 MediaTek Inc.
6. R1-2100762 Support 16QAM for NBIoT Lenovo, Motorola Mobility
7. R1-2101324 Design considerations to support 16-QAM for NB-IOT Sierra Wireless, S.A.
8. R1-2101509 Support of 16-QAM for NB-IoT Qualcomm Incorporated
9. R1-2101698 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
10. R1-2100570 Channel quality report for 16QAM in NB-IoT ZTE
11. R1-2101278 Channel quality reporting in NB-IoT to support 16QAM Huawei, HiSilicon
12. R1-2101701 Compendium of 16-QAM simulation results in UL and DL for NB-IoT Ericsson