**3GPP TSG RAN WG1 Meeting #102-e R1-20xxxxx**

**E-Meeting, August 17 – 28, 2020**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature summary on support of 16-QAM for unicast in UL and DL for NB-IoT**

**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 [2-10]

[102-e-LTE-Rel17\_NB\_IoT\_eMTC-01] Email discussion on support of 16-QAM for unicast in UL and DL for NB-IoT by 8/28 – Yubo (Huawei)

* Prioritize topics to be resolved in RAN1#102-e by 8/19

# Issues

Issue 1: The maximum TBS to support 16-QAM for unicast in DL.

There are following options:

* Maximum TBS is 4968 bits with *ISF*=7
	+ ZTE, Nokia, Nokia Shanghai Bell, Ericsson, MTK, Lenovo, Moto,
* Maximum TBS is 5352 bits with *ISF*=7
	+ ZTE,
* Maximum TBS is 5736 bits with *ISF*=7
	+ Huawei, HiSilicon
* New TBS entries with code rate less than 0.85 for all deployment scenarios
	+ Sierra Wireless
* Maximum TBS is 1352 bits with *ISF*=7
	+ Xiaomi
* Maximum TBS is 2x the R16 maximum TBS
	+ Qualcomm

Based on the majority view, the following is proposed:

Proposal 1: The maximum TBS to support 16-QAM for unicast in DL is 4968 bits with *ISF*=7

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Proposal 1 only holds for “stand-alone” and “guard-band” deployments so any case this needs to be reflected in the proposal. “In-band” deployments will have a different maximum since there are less resource elements available for data compared to the other two deployment modes. |
| Qualcomm | *I think there is a typo. It should be* ***4968*** *instead of 4986 – Yubo, please check. The proposed number is not an integer number of bytes.*Agree. To address Ericsson’s concerns, maybe we can add the following as:At least for standalone and guard-band deployments, the maximum TBS to support 16-QAM for unicast in DL is 4968 bits with *ISF*=7We would also like to point out that we don’t need to stick to TBSs defined already in LTE, so in this case we could multiply by 2 exactly the legacy TBS (2536 x 2) – in LTE we have the constraint of the codeword being compatible with the turbo-code interleaver, but for TBCC this is not needed. |
| Lenovo&MotoM | Support proposal 1 with QC’s clarification maximal TBS of 4968. For the maximal TBS, consider the three deployment scenarios, antenna port number, etc, unified TBS design/same maximal TBS for three modes is our preference, and legacy LTE table is the baseline If some of the TBS entry may lead the code rate larger than 0.932 for inband case, it can be handled/scheduled by eNB or it can be handled by TBS/MCS remapping design. |
| Mediatek | We are also ok for 5736 TBS considering some of NB-IOT 16QAM scenarios have same channel status as Phone, for example, wearable/Kids tracker, etc. And support Lenovo’s view, same maximal TBS for three operation modes is enough, e-NB should freely select suitable TBS according to the CQI. |
| Huawei/HiSilicon | Support maximum TBS 5736 bits with ISF=7 considering new scenarios such as heartbeat monitoring, voice commands for remote control etc, and we think 5736 bits can be used for at least some UEs in good coverage. And we also agree that 5736 bits may not be used in all cases e.g. in-band so some limitation for eNB scheduling is needed. |

Issue 2: The design of TBS to support 16-QAM for unicast in DL.

The following are proposed on the design of TBS:

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] |

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 |
| 22 | 520 | 1064 | 1608 | 2152 | 2664 | 3240 | 4264 | 5352 |
| 23 | 552 | 1128 | 1736 | 2280 | 2856 | 3496 | 4584 | 5736 |

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| [3] |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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 |
| 22 | 520 | 1064 | 1608 | 2152 | 2664 | 3240 | 4264 | 5352 |

 |
| [4] |

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 |

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| [5] | * Increasing the throughput with respect to QPSK by reducing the resource utilization in the time-domain (i.e., the throughput is not only increased through e.g., doubling the max TBS with respect to Rel-16).
* Avoid link adaptation issues, that is:
	+ Avoid large differences in achievable code rates when for a given ITBS, a different number of NSF is allocated
	+ Avoid large differences in achievable code rates when passing from QPSK to 16-QAM and vice versa (i.e., At 10% BLER, the SINR gap between QPSK and 16-QAM is no larger than ⁓ 3dB).
* Use a single TBS Table including TBS entries for both QPSK and 16-QAM
	+ In-band deployment is a subcase of the stand-alone and guard-band deployments unless a performance issue were found.

Standalone and gurad-band

|  |  |  |
| --- | --- | --- |
| 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 | 144 | 328 | 504 | 680 | 872 | 1032 | 1384 | 1736 |
| 10 | 176 | 376 | 584 | 776 | 1000 | 1192 | 1608 | 2024 |
| 11 | 224 | 488 | 744 | 1032 | 1256 | 1544 | 2024 | 2536 |
| 16-QAM only | 12 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 13 | 344 | 744 | 1128 | 1544 | 1928 | 2280 | 3112 | 3880 |
| 14 | 424 | 872 | 1352 | 1736 | 2280 | 2536 | 3496 | 4264 |
| 15 | 488 | 1000 | 1544 | 2024 | 2536 | 3112 | 4008 | 4968 |

Inband

|  |  |  |
| --- | --- | --- |
| Modulation Scheme |  | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| QPSK only | 0 | 0.13 | 0.09 | 0.09 | 0.09 | 0.09 | 0.1 | 0.1 | 0.09 |
| 1 | 0.16 | 0.13 | 0.12 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 |
| 2 | 0.18 | 0.16 | 0.18 | 0.16 | 0.15 | 0.15 | 0.14 | 0.15 |
| 3 | 0.21 | 0.21 | 0.22 | 0.19 | 0.18 | 0.19 | 0.19 | 0.19 |
| 4 | 0.26 | 0.24 | 0.25 | 0.23 | 0.23 | 0.24 | 0.24 | 0.23 |
| 5 | 0.32 | 0.28 | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| 6 | 0.37 | 0.33 | 0.31 | 0.34 | 0.35 | 0.34 | 0.34 | 0.35 |
| 7 | 0.42 | 0.41 | 0.39 | 0.41 | 0.4 | 0.39 | 0.41 | 0.41 |
| 8 | 0.47 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.45 |
| 9 | 0.55 | 0.58 | 0.58 | 0.58 | 0.59 | 0.58 | 0.58 | 0.58 |
| 10 | 0.66 | 0.66 | 0.67 | 0.66 | 0.67 | 0.67 | 0.67 | 0.67 |
| 11 | 0.82 | 0.84 | 0.84 | 0.87 | 0.84 | 0.86 | 0.84 | 0.84 |
| 16-QAM only | 12 | 0.50 | 0.51 | 0.51 | 0.51 | 0.52 | 0.50 | 0.51 | 0.52 |
| 13 | 0.61 | 0.63 | 0.63 | 0.64 | 0.64 | 0.63 | 0.64 | 0.64 |
| 14 | 0.74 | 0.74 | 0.75 | 0.72 | 0.76 | 0.70 | 0.72 | 0.71 |
| 15 | 0.84 | 0.84 | 0.86 | 0.84 | 0.84 | 0.86 | 0.83 | 0.82 |

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| [6] |

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|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 |

 |
| [7] |

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 |

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| [8] | Proposal 1: New TBS entries shall have a code rate of <=0.85 for all deployment scenarios (i.e. in-band, guard band, stand-alone)Proposal 2: To support 16-QAM and higher TBS, • The current values in the TBS table are kept• Add more columns with new TBS entries. FFS: number of columns and values.• For ITBS => 9, 16-QAM is used. |
| [9] |

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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~~1352  | ~~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~~  |
| 14 | 256 | 552 | 840 | 1128 | ~~1416~~1352 | ~~1736~~ | ~~2280~~ | ~~2600~~ |
| 15 | 280 | 600 | 904 | 1224 | ~~1544~~ | ~~1800~~ | ~~2472~~ | ~~2728~~ |
| 16 | 328 | 632 | 968 | 1288 | ~~1608~~ | ~~1928~~ | ~~2600~~ | ~~2984~~ |
| 17 | 336 | 680 | 1064 | ~~1416~~1352 | ~~1800~~ | ~~2152~~ | ~~2856~~ | ~~3240~~ |
| 18 | 376 | 776 | 1160 | ~~1544~~ | ~~1992~~ | ~~2344~~ | ~~3112~~ | ~~3624~~ |
| 19 | 408 | 840 | 1288 | ~~1736~~ | ~~2152~~ | ~~2600~~ | ~~3496~~ | ~~3880~~ |

 |
| [10] | **Proposal 1: The maximum TBS for DL 16-QAM is 2x the Rel-16 maximum TBS.** |

As the design of TBS table depends on the maximum TBS value, thus it is proposed:

Observation 1: The design of TBS table is discussed after the maximum TBS is agreed.

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | The design of the TBS table not only depends on the “maximum TBS,” but other technical aspects like the ones mentioned below in proposal 2 need to be taken into account. |
| Qualcomm | Yes, we need to agree the max TBS first. Then it is just a matter of removing some entries and adding new ones. |
| Lenovo &MotoM | Agree with the observation. Legacy LTE TBS is the baseline. |
| Mediatek | Agree the observation and we think down-selecting from Legacy LTE TBS is enough. |
| Huawei/HiSilicon | Agree observation 1 |

Issue 3: Scheduling of TBS and modulation to support 16-QAM for unicast in DL.

The following are proposed on scheduling of TBS and modulation:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Proposal 5: The introduction of 16-QAM shall not increase the NPDCCH blind decodes.Proposal 6: The introduction of 16-QAM shall avoid increasing DCI size. |
| [3] | ***Proposal 2: New MCS table should be defined for DL 16QAM.**** ***Alt 1: 4-bit MCS table***
* ***Alt 2: 5-bit MCS table***
 |
| [4] | **Proposal 6: The size of the MCS field in DCI N1 in UE-specific search space is increased to 5 bits.** |
| [5] | Standalone and gurad-band

|  |  |  |
| --- | --- | --- |
| 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 | 144 | 328 | 504 | 680 | 872 | 1032 | 1384 | 1736 |
| 10 | 176 | 376 | 584 | 776 | 1000 | 1192 | 1608 | 2024 |
| 11 | 224 | 488 | 744 | 1032 | 1256 | 1544 | 2024 | 2536 |
| 16-QAM only | 12 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 13 | 344 | 744 | 1128 | 1544 | 1928 | 2280 | 3112 | 3880 |
| 14 | 424 | 872 | 1352 | 1736 | 2280 | 2536 | 3496 | 4264 |
| 15 | 488 | 1000 | 1544 | 2024 | 2536 | 3112 | 4008 | 4968 |

Inband

|  |  |  |
| --- | --- | --- |
| Modulation Scheme |  | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| QPSK only | 0 | 0.13 | 0.09 | 0.09 | 0.09 | 0.09 | 0.1 | 0.1 | 0.09 |
| 1 | 0.16 | 0.13 | 0.12 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 |
| 2 | 0.18 | 0.16 | 0.18 | 0.16 | 0.15 | 0.15 | 0.14 | 0.15 |
| 3 | 0.21 | 0.21 | 0.22 | 0.19 | 0.18 | 0.19 | 0.19 | 0.19 |
| 4 | 0.26 | 0.24 | 0.25 | 0.23 | 0.23 | 0.24 | 0.24 | 0.23 |
| 5 | 0.32 | 0.28 | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| 6 | 0.37 | 0.33 | 0.31 | 0.34 | 0.35 | 0.34 | 0.34 | 0.35 |
| 7 | 0.42 | 0.41 | 0.39 | 0.41 | 0.4 | 0.39 | 0.41 | 0.41 |
| 8 | 0.47 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.45 |
| 9 | 0.55 | 0.58 | 0.58 | 0.58 | 0.59 | 0.58 | 0.58 | 0.58 |
| 10 | 0.66 | 0.66 | 0.67 | 0.66 | 0.67 | 0.67 | 0.67 | 0.67 |
| 11 | 0.82 | 0.84 | 0.84 | 0.87 | 0.84 | 0.86 | 0.84 | 0.84 |
| 16-QAM only | 12 | 0.50 | 0.51 | 0.51 | 0.51 | 0.52 | 0.50 | 0.51 | 0.52 |
| 13 | 0.61 | 0.63 | 0.63 | 0.64 | 0.64 | 0.63 | 0.64 | 0.64 |
| 14 | 0.74 | 0.74 | 0.75 | 0.72 | 0.76 | 0.70 | 0.72 | 0.71 |
| 15 | 0.84 | 0.84 | 0.86 | 0.84 | 0.84 | 0.86 | 0.83 | 0.82 |

 |
| [6] |

|  |  |  |
| --- | --- | --- |
| MCS Index | Modulation Order | TBS Index |
| 14 | 4 | 14 |
| 15 | 4 | 15 |
| 16 | 4 | 16 |
| 17 | 4 | 17 |
| 18 | 4 | 18 |
| 19 | 4 | 19 |
| 20 | 4 | 20 |
| 21 | 4 | 21 |

 |
| [7] |

|  |  |  |
| --- | --- | --- |
| MCS Index | Modulation Order  | TBS Index  |
| 0 | 2 | 0 |
| 1 | 2 | 1 |
| 2 | 2 | 3 |
| 3 | 2 | 4 |
| 4 | 2 | 5 |
| 5 | 2 | 7 |
| 6 | 2 | 8 |
| 7 | 2 | 9 |
| 8 | 4 | 11 |
| 9 | 4 | 12 |
| 10 | 4 | 13 |
| 11 | 4 | 14 |
| 12 | 4 | 16 |
| 13 | 4 | 17 |
| 14 | 4 | 18 |
| 15 | 4 | 20 |

***Proposal 2: To support 16QAM of NPDSCH, the MCS field in DCI format N1 is enlarged or reinterpreted, which needs further discussion.*** |
| [8] | Proposal 2: To support 16-QAM and higher TBS, • The current values in the TBS table are kept• Add more columns with new TBS entries. FFS: number of columns and values.• For ITBS => 9, 16-QAM is used. |
| [9] | **Proposal 2:** * **Redesign the mapping relationship between MCS index and TBS index to keep no increase in the MCS field in DCI**
* **Further discuss the detailed mapping schemes for TBS index, MCS index and modulation order.**
 |
| [10] | **Observation 1: The optimum *breakpoint* between different modulation schemes depends on the assumed overhead.****Proposal 2: Different deployment modes (from guardband/standalone to in-band with 4 CRS ports) should be evaluated when defining the mechanism for modulation/TBS determination.** **Proposal 3: RAN1 to study the benefits of defining different MCS/TBS tables for downlink 16-QAM in different deployment modes.****Proposal 4: RAN1 to discuss whether to introduce one or more “implicit MCS” entries for retransmissions in the MCS table for DL 16-QAM.** |

From the inputs, the following is proposed for further discussion:

Proposal 2: further study on the scheduling of TBS and modulation to support 16QAM:

* **MCS field size: [4, 5] bits**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | The bullet list above misses other important technical aspects such as the achievable code rates and the avoidance of link adaptation issues. We think that proposal 2 should be updated as follows:Proposal 2: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in DL:* **MCS field size: [4, 5] bits**
* **Achievable code rates [<=0.85]**
* **Avoidance of link-adaptation issues**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**
 |
| Qualcomm | We think the list of issues in the proposal is a good starting point. We would propose to add the following (on top of E///’s)Proposal 2: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in DL:* **MCS field size: [4, 5] bits**
* **Achievable code rates [<=0.85]**
* **Avoidance of link-adaptation issues**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**
* **Applicability of repetitions**
 |
| Lenovo&MotoM | Support the first three issues to be studied, following comments are our preference:1. Follow the legacy DCI size, MCS field size: 4 bits
2. The break point is based on further evaluation
3. Prefer unified design, different TBS/MCS remapping for inband is also OK.
 |
| Mediatek | Support this proposals. We prefer to 5 bits MCS. We think avoidance of link-adaptation issues could be equivalent to keeping the linearity of Spectrum efficiency and it seems that proposed TBS has no such issues. |
| Huawei/HiSilicon | The TBS Table design, resource assignment, TBS allocation and achievable code rate are all related to maximum TBS. So we think adding the sub-bullet achievable code rates is enough considering the code rate may larger than 0.85 in some cases. And some editorial changes below**Proposal 2: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in DL considering:*** **MCS field size: [4, 5] bits**
* **Achievable code rates ~~[<=0.85]~~**
* **Avoidance of link-adaptation issues**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**
* **Applicability of repetitions**

And we are not so clear about the avoidance of link-adaptation issue, so perhaps this sub-bullet may need some more clarification. |

Issue 4: The TBS design to support 16-QAM for unicast in UL.

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

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Proposal 2: For 16-QAM, the UL maximum TBS with 2536 bits can be mapped to at least 5 RUs.

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 5: UL 16QAM is supported only for multi-tone transmission.*** |
| [4] |

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

 |
| [5] | Proposal 2 The design targets to introduce 16-QAM for NB-IoT in UL include:• Increasing the throughput with respect to QPSK by reducing the resource utilization in the time-domain.• Avoid link adaptation issues, that is:o Avoid large differences in achievable code rates when for a given ITBS, a different number of RUs is allocated.o Avoid large differences in achievable code rates when passing from QPSK to 16-QAM and vice versa (i.e., At 10% BLER, the SINR gap between QPSK and 16-QAM is no larger than ⁓ 3dB).• Use a single TBS Table including TBS entries for both QPSK and 16-QAM. |
| [6] | Proposal 1 Adding TBS index ITBS 14 to ITBS 21 in NB-iot TBS table, DL maximum TBS should be extended to 4968 bits. UL maximum TBS should be extended to 4968 bits to get 310.5kbps UL data rate. |
| [7] |

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

***Proposal 7: Support 16QAM for NPUSCH needs further study:**** ***Option1: Extend TBS table and generate modulation, TBS and MCS table.***
* ***Option2: Reinterpret the number of resource unit for modulation order of 16QAM.***
 |

Based on the inputs, the following can be proposed:

Proposal 3: RAN1 to down-select from the following options to support 16-QAM for unicast in UL.

* Option 1:

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 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  |
| 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 |  |  |  |

* Option 2:

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

* Option 3:

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

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | In UL there are almost the same technical considerations as for DL, thus we are not ready to perform a down-selection since UL needs to be subject to a study that is similar as the one proposed for DL. None of the TBS Tables above have been subject to evaluations as for example knowing if they incur in link-adaption issues, including the break/switching point between modulation schemes. |
| Qualcomm | This seems like stage-3 design. Could we agree first to a set of principles? |
| Lenovo &MotoM | Support the proposal and our preference is option 3The option 3 table is fully from the legacy TS36.213 Table 7.1.7.2.1-1: Transport block size table (dimension 44×110) and only remove the TBS larger than 2536.If we insert some of the new TBS entry to the table, it will lead different code rate for different  with same , which is not easy for eNB scheduling |
| Mediatek | We prefer to option3 and as mentioned in [6], we propose to extend the maximal TBS to the same as DL. |
| Huawei/HiSilicon | We support option 1 since 2536bits can also be used in smaller number of RUs for 16QAM in uplink. And we are also fine to further discuss based on these options later. |

Issue 5: Scheduling of TBS and modulation to support 16-QAM for unicast in UL.

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

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Proposal 5: The introduction of 16-QAM shall not increase the NPDCCH blind decodes.Proposal 6: The introduction of 16-QAM shall avoid increasing DCI size. |
| [3] | ***Proposal 5: UL 16QAM is supported only for multi-tone transmission.******Proposal 6: 4-bit MCS table should be baseline for UL 16QAM.***Table 8.6.1-2: Modulation and TBS index table for PUSCH

|  |  |  |
| --- | --- | --- |
| MCS Index | Modulation Order | TBS Index |
| **0** | 2 | 0 |
| **1** | 2 | 1 |
| **2** | 2 | 2 |
| **3** | 2 | 3 |
| **4** | 2 | 4 |
| **5** | 2 | 5 |
| **6** | 2 | 6 |
| **7** | 2 | 7 |
| **8** | 2 | 8 |
| **9** | 2 | 9 |
| **10** | 2 | 10 |
| **11** | 4 | 10 |
| **12** | 4 | 11 |
| **13** | 4 | 12 |
| **14** | 4 | 13 |
| **15** | 4 | 14 |

 |
| [4] | **Proposal 11: The size of the MCS field in DCI N0 in UE-specific search space is increased to 5 bits.****Proposal 12: 16-QAM is not supported for sub-PRB allocation.** |
| [5] | Proposal 2 The design targets to introduce 16-QAM for NB-IoT in UL include:• Increasing the throughput with respect to QPSK by reducing the resource utilization in the time-domain.• Avoid link adaptation issues, that is:o Avoid large differences in achievable code rates when for a given ITBS, a different number of RUs is allocated.o Avoid large differences in achievable code rates when passing from QPSK to 16-QAM and vice versa (i.e., At 10% BLER, the SINR gap between QPSK and 16-QAM is no larger than ⁓ 3dB).• Use a single TBS Table including TBS entries for both QPSK and 16-QAM. |
| [7] | ***Proposal 7: Support 16QAM for NPUSCH needs further study:**** ***Option1: Extend TBS table and generate modulation, TBS and MCS table.***
* ***Option2: Reinterpret the number of resource unit for modulation order of 16QAM.***
 |
| [10] | **Proposal 11: RAN1 to discuss whether to introduce one or more “implicit MCS” for retransmissions in the MCS table for UL 16-QAM.****Proposal 15: UL 16-QAM is applicable at least to NPUSCH with full-PRB allocations. FFS NPUSCH with sub-PRB allocations.** |

Based on the input, the following is proposed:

Proposal 4: further study on the scheduling of TBS and modulation to support 16QAM:

* **MCS field size: [4, 5] bits**
* **The break point between different modulation schemes**
* **Indication of modulation scheme for retransmissions**
* **Single-tone/multi-tone**

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Similar comment as for DL, we think proposal 4 misses’ other important technical aspects such as the achievable code rates and the avoidance of link adaptation issuesBelow we have added a similar proposal as for DL, but also one related to throughput increase considering that the WID says that a new max TBS is not for UL but only for the DL case.Proposal x: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in UL:* **MCS field size: [4, 5] bits**
* **Achievable code rates [<=0.85]**
* **Avoidance of link-adaptation issues**
* **Throughput increase while keeping the max TBS from Rel-16**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**
 |
| Qualcomm | Similar comment as before, adding the following.Proposal x: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in UL:* **MCS field size: [4, 5] bits**
* **Achievable code rates [<=0.85]**
* **Avoidance of link-adaptation issues**
* **Throughput increase while keeping the max TBS from Rel-16**
* **The break point between different modulation schemes**
* **Impacts of deployment modes**
* **Indication of modulation scheme for retransmissions**
* **Applicability of repetitions**
* **Applicability to different number of subcarriers.**
 |
| Lenovo &MotoM | For uplink, things are a little different. Some companies prefer the remapping of the MCS and TBS, some companies prefer to reinterpret the number of resource unit, both of the options should be considered at this stage. Agree the comments from E/// and QC in the main bullet.Further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in UL: |
| Mediatek | Same as DL, we prefer to 5bits MCS and also support 16QAM is only used for multi-tones. |
| Huawei, HiSilicon | Similar opinions as DL with following changes. In addition, the impacts of deployment modes for UL are not needed.Proposal 4 is updated:Proposal x: further study on TBS Table design, resource assignment and TBS allocation to support 16QAM in UL:* **MCS field size: [4, 5] bits**
* **Achievable code rates ~~[<=0.85]~~**
* **Avoidance of link-adaptation issues**
* **Throughput increase while keeping the max TBS from Rel-16**
* **The break point between different modulation schemes**
* **~~Impacts of deployment modes~~**
* **Indication of modulation scheme for retransmissions**
* **Applicability of repetitions**
* **Applicability to different number of subcarriers**

And we are not so clear about the avoidance of link-adaptation issue, so perhaps this sub-bullet may need some more clarification. |

Issue 6: Power allocation.

There are following proposals on power allocation

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Proposal 7: Signal the ratio of NPDSCH EPRE to NRS EPRE for 16-QAM. FFS the detailed signaling.Proposal 8: For 16-QAM, FFS whether or not the PDSCH EPRE is the same in OFDM symbols containing NRS and not containing NRS. |
| [3] | ***Proposal 3: UE-specific DL power allocation between NPDSCH and NRS can be supported to handle different modulation modes.*** |
| [4] | **Proposal 7: Discuss whether the ratio of NPDSCH EPRE to NRS EPRE for 16-QAM should be different than legacy and whether UE-specific signaling is needed.** |
| [7] | ***Proposal 4: Network should semi-statically configure three types of NPDSCH EPRE separately.**** Type A OFDM: without NRS or CRS, symbol (1),2,4
* Type B OFDM: with NRS, symbol 5,6
* Type C OFDM: with CRS, symbol 0,(1),3
 |
| [10] | **Observation 2: 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: Define three different levels** $ρ\_{A},ρ\_{B},ρ\_{C}$ **of EPRE of NPDSCH with respect to EPRE of NRS:*** $ρ\_{A}$**: 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.**
 |

Based on the input, the following is proposed:

Proposal 5: The signal of ration of NPDSCH EPRE to NRS EPRE is supported. FFS the details signaling and following cases

* **NPDSCH in symbols without NRS and CRS**
* **NPDSCH in symbols with CRS and without NRS**
* **NPDSCH in symbols without CRS and with NRS**

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | We think that at this point there are more fundamental issues to be discussed. The potential gains from modifying the power allocation need to be quantified and to do that we need to have a TBS Table settled. |
| Qualcomm | We agree with the proposal. I don’t think any evaluation is needed for this, the reality is that, in Rel-16 and earlier, the eNB can modify the power allocation without a very small impact in UE performance (due to QPSK modulation). With multi-level constellations, any mismatch in power between eNB/UE would lead to errors in the channel.Just a minor typo correction and editorial:The signal of ratio of NPDSCH EPRE to NRS EPRE is supported. FFS the details signaling and following cases* **NPDSCH in symbols without NRS and CRS**
* **NPDSCH in symbols with CRS**
* **NPDSCH in symbols with NRS**
 |
| Lenovo &MotoM | Support the proposal with QC’s update. It is obvious that three different types of OFDM symbols should be considered at least for inband case (please clarify in the proposal), we need further discussion whether and how to signal the power ratio. |
| Mediatek | We support QC’s update. |
| Huawei, HiSilicon | Support the proposal with a little update for better understanding:**Proposal 5: The signal of ratio of NPDSCH EPRE to NRS EPRE is supported. FFS the details signaling and following cases*** **NPDSCH in symbols without NRS and CRS**
* **NPDSCH in symbols with CRS ( only for “In-band” deployment)**
* **NPDSCH in symbols with NRS**
 |

Issue 7: Evaluation assumptions.

There are following proposals on evaluation assumptions:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [2] | Table 5: Simulation assumptions for DL

|  |  |
| --- | --- |
| **Parameter** | **Value/Description** |
| Operation mode for DL | Stand-alone |
| Number of antennas | 1T1R |
| Channel model  | AWGN |
| Frequency Resource | 1 PRB |
| Number of repetitions | 1 |
| Number of subframes | 5 |
| Modulation Order | QPSK, 16-QAM |
| Noise Estimation | Ideal |
| Channel Estimation | Ideal |
| Frequency Offset | 0 |
| Time Offset | 0 |

Table 6: Simulation assumptions for UL

|  |  |
| --- | --- |
| **Parameter** | **Value/Description** |
| Number of antennas | 1T2R |
| Channel model  | AWGN |
| Frequency Resource | 12-tone |
| Number of repetitions | 1 |
| Number of RUs | 5 |
| Modulation Order | QPSK, 16-QAM |
| Noise Estimation | Ideal |
| Channel Estimation | Ideal |
| Frequency Offset | 0 |
| Time Offset | 0 |

 |
| [5] |

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Propagation conditions | AWGN, ETU |
| Fading | Rayleigh, 1 Hz Doppler spread |
| Raster offset | Stand-alone: 0Hz; in-band and guard-band: 7.5 kHz |
| Device antenna configuration | One transmit antenna and one receive antenna |
| Base station antenna configuration | Stand-alone, guard-band, and in-band: Two transmit antennas and two receive antennas |
| MCL | ≤ 144 dB |
| Number of NPDCCH/NPDSCH REs per subframe | Stand-alone and guard-band: 152, In-band: 104 |
| Resource Bandwidth | DL: 1 PRB | UL: 1 PRB, optional 3, 6 tones. |
| Number of repetitions | DL(NPDCCH/NPDSCH): 1 | UL(NPDCCH/NPUSCH): 1 |
| Number of HARQ processes | Up to 2 (Cat N2) |
| Max number of retransmissions | Up to 4 |
| Coding Method | DL: Convolutional coding | UL: Turbo coding |
| Channel Estimation | Ideal, Realistic |
| 16-QAM modulation | Gray coded QAM |
| Valid NB-IoT subframes | All subframes not carrying NPBCH, NPSS, and NSSS are assumed valid subframes. |

 |
|  |  |
|  |  |

As evaluation would be needed for further discussion such as MCS, it is proposed that:

Proposal 6: RAN1 to discuss and agree on the evaluation assumptions for support of 16QAM in DL and UL for NB-IoT.

Please input your comments in the following table

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | The evaluation is an important part towards the selection of the TBS Tables for both UL and DL. We think that the set of simulation assumptions provided in [5] is more complete, and we can add on it any other aspect other companies might consider important that is not in there yet. |
| Qualcomm | We agree that we need to discuss this. [2] can be a good starting point with the following changes:- Add other deployment modes (otherwise, the switching point may not be correctly determined)- Add realistic channel estimation. |
| Lenovo &MotoM | Support the proposal |
| Mediatek | We support the proposal and propose to add realistic channel estimation. |
| Huawei, HiSilicon | Support the proposal, and [2] can be a starting point. |

Issue 8: Others

If you have other issues that should be prioritized in this meeting, please input in the following table:

|  |  |
| --- | --- |
| Sourcing | proposals |
| Qualcomm | We think we need to discuss also the following (although it is not urgent, the last two should be immediate):* Power control changes for uplink (if needed).
* Interaction with USS/CSS.
* Configuration aspects / capability.
 |
| MTK |  |
|  |  |
|  |  |
|  |  |
|  |  |

# Summary

# References

1. RP-201306, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#88e, E-meeting, June 2020.
2. R1-2005304 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2005479 Discussion on UL and DL 16QAM for NB-IoT ZTE
4. R1-2005529 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
5. R1-2005557 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
6. R1-2005648 Considerations on support of 16QAM for NB-IOT MediaTek Inc.
7. R1-2005837 Support 16QAM for NBIoT Lenovo, Motorola Mobility
8. R1-2005941 Design consideration to support 16-QAM for NB-IOT Sierra Wireless, S.A.
9. R1-2005974 Initial discussion on support of 16 QAM for NB-IoT Beijing Xiaomi Software Tech
10. R1-2006192 Support of 16-QAM for NB-IoT Qualcomm Incorporated