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

**eMeeting, Jan 25-Feb 5, 2021**

**Source: Moderator (Ericsson)**

**Title: Draft summary for introduction of 1024QAM for NR DL**

**Agenda item:** **8.16**

**Document for:** **Discussion and Decision**

# 1 Introduction

This document provides a summary from the contributions submitted for under agenda item 8.16 for introduction of DL 1024-QAM for NR FR1 for email thread [104-e-NR-1024QAM-01].

# 2. Discussion

Below is a short moderator summary based on the tdocs [3-12] submitted for RAN1#104-e.

1. **4-bit CQI table with 1024-QAM**
   * Alt 1: Reuse LTE CQI table with 1024-QAM entries [4][5][6][7][9][11][12]
     + Note: for CQI index 14, the SE value (from LTE) is slightly updated from 8.3321 to 8.3301
     + Has 2 CQI entries for 1024-QAM
   * Alt 2: CQI table with 3 CQI entries for 1024-QAM [3]
   * Common MCSes between Alt 1 and Alt 2 are highlighted below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Alt 1 |  |  |  |  | Alt 2 |  |  |  |
| **CQI index** | **modulation** | **code rate x 1024** | **Efficiency** |  | **CQI index** | **modulation** | **code rate x 1024** | **Efficiency** |
| 0 | out of range |  |  |  | 0 | out of range | | |
| 1 | QPSK | 78 | 0.1523 |  | 1 | QPSK | 78 | 0.1523 |
| 2 | QPSK | 193 | 0.377 |  | 3 | QPSK | 449 | 0.877 |
| 3 | QPSK | 449 | 0.877 |  | 5 | 16QAM | 490 | 1.9141 |
| 4 | 16QAM | 378 | 1.4766 |  | 7 | 64QAM | 466 | 2.7305 |
| 5 | 16QAM | 616 | 2.4063 |  | 8 | 64QAM | 567 | 3.3223 |
| 6 | 64QAM | 567 | 3.3223 |  | 9 | 64QAM | 666 | 3.9023 |
| 7 | 64QAM | 666 | 3.9023 |  | 10 | 64QAM | 772 | 4.5234 |
| 8 | 64QAM | 772 | 4.5234 |  | 11 | 64QAM | 873 | 5.1152 |
| 9 | 64QAM | 873 | 5.1152 |  | 12 | 256-QAM | 711 | 5.5547 |
| 10 | 256QAM | 711 | 5.5547 |  | 13 | 256-QAM | 797 | 6.2266 |
| 11 | 256QAM | 797 | 6.2266 |  | 14 | 256-QAM | 885 | 6.9141 |
| 12 | 256QAM | 885 | 6.9141 |  | 15 | 256-QAM | 948 | 7.4063 |
| 13 | 256QAM | 948 | 7.4063 |  | 13 | 1024-QAM | 822 | 8.0273 |
| 14 | 1024QAM | 853 | 8.3301 |  | 14 | 1024-QAM | 885 | 8.6425 |
| 15 | 1024QAM | 948 | 9.2578 |  | 15 | 1024-QAM | 948 | 9.2578 |

1. **5-bit MCS table with 1024-QAM entries**
   * Adopt NR 256-QAM MCS table with following modification [3][4][5][6][7][9][10][11][12]
     + Remove M entries (between 0 and 27) to accommodate M entries for 1024-QAM MCSes
     + Add One implicit MCS entry for 1024-QAM [3][4][5][6][7][9][10][11][12]
     + Add M-1 Explicit MCS entries for 1024-QAM (with modulation order/Target Code rate/Spectral efficiency)
       - Alt 1 : M=5, four explicit 1024-QAM entries [4][5][6][9][11][12]
       - Alt 2 : M=6, five explicit 1024-QAM entries [7]
       - Alt 3 : M=6, five explicit 1024-QAM entries [10]
       - Alt 4 : M=7, six explicit 1024-QAM entries [3]



* + Regarding M entries to be removed from NR 256-QAM MCS table, different alternatives were proposed:
    - M=5 ([4][5][6][9][11][12])
      * Alt 1: {5, 7, 9, 12, 14}
        + [4][6][9]
      * Alt 2: {6, 8, 10, 12, 14}
        + [5]
      * Alt 3: {2,4,6,8,10}
        + [11][12]
      * Alt 4: {1,3,5,7,9}
        + [11]
    - M=6 ([7])
      * {5, 7, 9, 12, 14, 27}
    - M=6 ([10])
      * {1, 5, 7, 9, 12, 14}
    - M= 7 ([3])
      * {2, 4, 6, 8, 10, 12, 14}

1. **RRC configuration and DCI formats**
   * Use of 1024-QAM MCS table with DCI format 1\_2
     + Allow : [4][7][10][11][12], with separate RRC signalling to indicate the use of 1024-QAM MCS table for DCI format 1\_2 than DCI format 1\_1
     + Do not allow : [5]
   * Send LS to RAN2 [12]
2. **Remaining aspects of 1024-QAM including spec impacts, etc**
   * TPs to incorporate 1024-QAM feature in specification, including
     + TBS [5][12]
     + PTRS reception procedure [6][9][12]
     + MCS [12]
     + DataRateCC [12]
   * Use actual overhead instead of xOverhead to determine the TBS for the SPS PDSCH [3]
   * Introduce new RRC signalling to indicate the use of 1024-QAM MCS table with SPS-Config [10]
   * Processing time relaxation [9]
   * UE capability reporting [5]
   * System-level simulation to identify the cell size(s) [3]
   * Reduce the efforts and specification impacts of DL 1024QAM as much as possible [8]
   * Identify the crossover SINR point between 256QAM and 1024QAM and the cell size to facilitate the clarification of using scenario. [8]

# 1st round

### Proposal 1

* For supporting 1024-QAM in NR downlink, adopt the LTE 1024-QAM CQI table entries
  + Note: for CQI index 14, the SE value (from LTE) is slightly updated

|  |  |  |  |
| --- | --- | --- | --- |
| **CQI index** | **modulation** | **code rate x 1024** | **Efficiency** |
| 0 | out of range | | |
| 1 | QPSK | 78 | 0.1523 |
| 2 | QPSK | 193 | 0.3770 |
| 3 | QPSK | 449 | 0.8770 |
| 4 | 16QAM | 378 | 1.4766 |
| 5 | 16QAM | 616 | 2.4063 |
| 6 | 64QAM | 567 | 3.3223 |
| 7 | 64QAM | 666 | 3.9023 |
| 8 | 64QAM | 772 | 4.5234 |
| 9 | 64QAM | 873 | 5.1152 |
| 10 | 256QAM | 711 | 5.5547 |
| 11 | 256QAM | 797 | 6.2266 |
| 12 | 256QAM | 885 | 6.9141 |
| 13 | 256QAM | 948 | 7.4063 |
| 14 | 1024QAM | 853 | 8.3301~~21~~ |
| 15 | 1024QAM | 948 | 9.2578 |

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 1)** |
| vivo | Support | The reasons for update CQI index 14 are as below:   * All SE can be deduced based on CR/1024\*Qm except CQI index 14. * When we use CR and SE to calculate TBS respectively, two different TBS values would be acquired, which is unexpected. The tiny SE difference will amplify with the increase of allocated PRBs. * The SE values have an impact on MCS table design, since the medium 1024QAM entries are interpolated based on the SE values of 1024QAM CQI table. |
| CATT | Support | We noticed that the same update is proposed for LTE 1024 CQI table in R1-2101281. It is reasonable to have the same update for NR. |
| Intel |  | No strong preference as both options are equivalent. |
| Huawei, HiSilicon | Not support | We are fine to adjust the SE to align the SE and coding rate. However, the proposed CQI table has non-uniform SNR spacing for medium to high SNR region, therefore, we prefer to add three entries for 1024QAM. |

### Proposal 2

* For supporting 1024-QAM in NR downlink, adopt a five-bit MCS table with 1024-QAM entries:
  + Remove M explicit MCS entries (from MCS indices 0-27) from the NR 256QAM MCS table and add M new entries for 1024QAM
  + M=5
  + Add one implicit MCS entry corresponding to 1024-QAM
  + Add M-1 explicit MCS entries corresponding to 1024-QAM as follows:

|  |  |  |
| --- | --- | --- |
| modulation | code rate x 1024 | Efficiency |
| 10 | 806 | 7.8711 |
| 10 | 853 | 8.3301 |
| 10 | 900.5 | 8.7939 |
| 10 | 948 | 9.2578 |

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 2)** |
| vivo | Support | Sightly prefer to replace the entry {806, 7.8711} to {805.5, 7.8662}, since the spectral efficiency of later entry is closer to the interpolated value of (8.3301+7.4063)/2=7.8682. However, for progress, we can accept the minute difference. |
| CATT | Support | Although we prefer {805.5, 853, 900, 948}/1024, the proposal is also fine with us. |
| Intel | Partially support | Prefer M = 6 (additional MCS to be replaced is MCS#23) |
| Huawei, HiSilicon | Partially support | We are fine with the first and third sub-bullet. For the second and fourth sub-bullets, the SNR spacing between the proposed 1024QAN entries are larger than the medium SNR region, which is an optimization for high SRN region. We prefer M=6 and add 5 explicit MCS entries for 1024QAM. |

### Proposal 3

* For supporting 1024-QAM in NR downlink, remove following M (=5) MCS entries from the NR 256-QAM MCS table
  + 5, 7, 9, 12, 14

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 3)** |
| vivo | Not support | Follow NR MCS table design principle, CQI entries should be kept, so {5,7,9} should be kept as they were already included in the 1024-QAM CQI table.  To make comparable with LTE, we prefer to remove entries {6, 8, 10, 12, 14} from the 256QAM table, while keeping the lowest MCS. |
| CATT | Support |  |
| Intel | Partially support | Prefer to add MCS#23 to be replaced with 1024QAM |
| Huawei, HiSilicon | Not support | As the 1024QAM is used for UEs with good coverage, the entries to be removed should be with low spectral efficiencies. In addition, it would be preferred if the entries listed in CQI table are not removed. |

### Proposal 4

* Introduce separate RRC signaling to indicate use of 1024-QAM MCS table for DCI format 1\_2.
* Send LS to RAN2 on RRC signaling for 1024-QAM.

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 4)** |
| vivo | Not support | For DCI format 1\_2 for URLLC scheduling, the motivation to support 1024QAM is unclear. It can be observed from our simulation that the UPT performance is not obvious for 1024QAM and edge users will suffer performance degradation.    It should be noted that the unit of above UPT should be Mbit/TTI in our original Tdoc R1-2100484. |
| CATT | Support |  |
| Intel | Support |  |
| Huawei, HiSilicon | Support. |  |

### Proposal 5

* Adopt TP in section 5 (R1-2100484) for TBS determination for subclause 5.1.3.2 of TS 38.214.

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 5)** |
| vivo | Support |  |
| CATT | Support |  |
| Huawei, HiSilicon | Support | However, just as the last meeting, it would be better to be clarified that such TPs are only for reference for the editors when the editors’ CR is to be prepared. |

### Proposal 6

* Adopt TP4 from Annex D (R1-2101564) for PT-RS determination for subclause 5.1.6.3 of TS 38.214.

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 6)** |
| vivo | Support |  |
| CATT | Support |  |
| Huawei, HiSilicon | Support | However, just as the last meeting, it would be better to be clarified that such TPs are only for reference for the editors when the editors’ CR is to be prepared. |

### Proposal 7

* Adopt TP2 from Annex D (R1-2101564) for MCS determination for subclause 5.1.3.1 of TS 38.214.

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 7)** |
| vivo | Support |  |
| CATT | Support |  |
| Huawei, HiSilicon | Support | However, just as the last meeting, it would be better to be clarified that such TPs are only for reference for the editors when the editors’ CR is to be prepared. |

### Proposal 8

* Adopt TP1 from Annex D (R1-2101564) for per-cell data rate constraint for subclause 5.1.3 of TS 38.214.

Companies are requested to indicate their view about the above proposal in the Table below.

|  |  |  |
| --- | --- | --- |
| **Company Name** | **support/not support** | **Comments (Proposal 8)** |
| vivo | Support |  |
| CATT | Support |  |
| Huawei, HiSilicon | Support | However, just as the last meeting, it would be better to be clarified that such TPs are only for reference for the editors when the editors’ CR is to be prepared. |

# 2nd round proposals (TBD)

# 3 Conclusions

TBD

# 4 References

1. [*RP-202044*](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_89e/Docs/RP-202044.zip)*,* New WID on Introduction of DL 1024QAM for NR FR1, RAN Meeting #89e,Sep 2020
2. [*RP-202886*](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Docs/RP-202886.zip)*,* Revised WID on Introduction of DL 1024QAM for NR FR1, RAN Meeting #90,Dec 2020
3. R1-2100215 On support of DL 1024QAM for NR FR1 Huawei, HiSilicon
4. R1-2100369 DL 1024QAM for NR FR1 CATT
5. R1-2100484 On supporting DL 1024QAM for NR FR1 vivo
6. R1-2100532 Discussion on DL 1024QAM for NR FR1 ZTE , Sanechips
7. R1-2100686 Support of 1024QAM Intel Corporation
8. R1-2101071 Discussion on DL 1024QAM for NR FR1 CMCC
9. R1-2101246 On remaining issues of DL 1024QAM for NR FR1 Samsung
10. R1-2101421 Support for NR DL 1024 QAM in FR1 Nokia, Nokia Shanghai Bell
11. R1-2101496 1024-QAM for NR PDSCH Qualcomm Incorporated
12. R1-2101564 1024QAM for NR DL Ericsson

# 5 Annex A (Agreements from RAN1#103-e)

Agreements:

* Introduce new RRC signaling to indicate use of 1024-QAM CQI table.
* For supporting 1024-QAM in NR downlink, adopt the LTE 1024-QAM constellation.
* 1024-QAM MCS table can be used only with DCI format with CRC scrambled by C-RNTI or CS-RNTI.

Agreements:

* Introduce new RRC signaling to indicate use of 1024-QAM MCS table for at least DCI format 1\_1
  + FFS : support of 1024-QAM MCS table for DCI format 1\_2
    - Note: If 1024-QAM MCS table for DCI format 1\_2 is supported, separate RRC signaling is used for each of the two DCI formats 1\_1 and 1\_2, respectively
  + FFS : whether the RRC signaling is only introduced in PDSCH-Config or it can also be separately configured in SPS-Config

Agreements:

* RRC signaling (mcs-Table-r17) to indicate use of 1024-QAM MCS table for DCI format 1\_1 is present only in PDSCH-config
* When UE is configured with mcs-Table-r17 set to ‘qam1024’ in PDSCH-Config,
  + UE uses 1024-QAM MCS table for PDSCH scheduled with a DCI format 1\_1 with CRC scrambled by C-RNTI,
  + UE uses 1024-QAM MCS table for PDSCH scheduled with the DCI format 1\_1 with CRC scrambled by CS-RNTI if the UE is not configured with mcs-Table in SPS-Config
* Note: If 1024-QAM MCS table for DCI format 1\_2 is supported, similar approach is used for 1024-QAM MCS table usage with DCI format 1\_2

Agreements:

* Adopt following TP for in 38.212, subclause 5.4.2.1 for TBS\_LBRM determination.

5.4.2.1  Bit selection
The bit sequence after encoding   from Clause 5.3.2 is written into a circular buffer of length   for the  -th coded block, where   is defined in Clause 5.3.2.
For the  -th code block, let   if   and   otherwise, where  ,  ,   is determined according to Clause 6.1.4.2 in [6, TS 38.214] for UL-SCH and Clause 5.1.3.2 in [6, TS 38.214] for DL-SCH/PCH, assuming the following:
- maximum number of layers for one TB for UL-SCH is given by X, where
- if the higher layer parameter maxMIMO-Layers of PUSCH-ServingCellConfig of the serving cell is configured, X is given by that parameter 
- elseif the higher layer parameter maxRank of pusch-Config of the serving cell is configured, X is given by the maximum value of maxRank across all BWPs of the serving cell
- otherwise, X is given by the maximum number of layers for PUSCH supported by the UE for the serving cell
- maximum number of layers for one TB for DL-SCH/PCH is given by the minimum of X and 4, where
- if the higher layer parameter maxMIMO-Layers of PDSCH-ServingCellConfig of the serving cell is configured, X is given by that parameter
- otherwise, X is given by the maximum number of layers for PDSCH supported by the UE for the serving cell
- if the higher layer parameter mcs-Table-r17 given by a pdsch-Config for at least one DL BWP of the serving cell is set to 'qam1024', maximum modulation order   is assumed for DL-SCH, elseif the higher layer parameter mcs-Table given by a pdsch-Config for at least one DL BWP of the serving cell is set to 'qam256', maximum modulation order   is assumed for DL-SCH; otherwise else a maximum modulation order   is assumed for DL-SCH; 
Unchanged parts are omitted


Agreements:

* Adopt following text proposal for TS 38.201, subclause 4.2.2.

|  |
| --- |
| -------------------------------------------------------- Omitted -----------  4.2.2          Physical channels and modulation  -------------------------------------------------------- Omitted ---------------  The modulation schemes supported are  -    in the downlink, QPSK, 16QAM, 64QAM, ~~and~~ 256QAM and 1024 QAM  -    in the uplink, QPSK, 16QAM, 64QAM and 256QAM for OFDM with a CP and π/2-BPSK, QPSK, 16QAM, 64QAM and 256QAM for DFT-s-OFDM with a CP  -------------------------------------------------------- Omitted ------ |

Agreements:

* Adopt following TP for 38.211 to reflect the agreed 1024-QAM constellation.



Agreements:

* Adopt following TP to 38.211, subclause 7.3.1.2, to reflect 1024-QAM support for PDSCH

Section 7.3.1.2

Table 7.3.1.2-1: Supported modulation schemes.

|  |  |
| --- | --- |
| Modulation scheme | Modulation order |
| QPSK | 2 |
| 16QAM | 4 |
| 64QAM | 6 |
| 256QAM | 8 |
| 1024QAM | 10 |

Agreements:

* Adopt following TP for 38.214, subclause 5.2.2.1, reflecting the 1024-QAM CQI table usage based on corresponding RRC parameter as follows.
  + Note : RAN1 to further align with the RAN2 signaling design

5.2.2.1   Channel quality indicator (CQI)

-------------------------------------------------------- Omitted ----------------------------------------------------------------------------------------------------------------------

The CQI indices and their interpretations are given in Table 5.2.2.1-2 or Table 5.2.2.1-4 for reporting CQI based on QPSK, 16QAM and 64QAM. The CQI indices and their interpretations are given in Table 5.2.2.1-3 for reporting CQI based on QPSK, 16QAM, 64QAM and 256QAM. The CQI indices and their interpretations are given in Table 5.2.2.1-5 for reporting CQI based on QPSK, 16QAM, 64QAM, 256QAM and 1024 QAM.

Based on an unrestricted observation interval in time unless specified otherwise in this Clause, and an unrestricted observation interval in frequency, the UE shall derive for each CQI value reported in uplink slot *n* the highest CQI index which satisfies the following condition:

-    A single PDSCH transport block with a combination of modulation scheme, target code rate and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding:

-    0.1, if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures ‘table1’ (corresponding to Table 5.2.2.1-2), or ‘table2’ (corresponding to Table 5.2.2.1-3), or if the higher layer parameter *cqi-Table-r17* in *CSI-ReportConfig* configures ‘table4’ (corresponding to Table 5.2.2.1-5)

-    0.00001, if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures ‘table3’ (corresponding to Table 5.2.2.1-4).

-------------------------------------------------------- Omitted -------------------------------------------------------------------------------------------------------------------------

Agreements:

* Companies are encouraged to use below link-level simulation assumptions for assessing at least transition point between 256-QAM and 1024-QAM.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Carrier frequency, SCS, System BW | 3.5GHz, 30kHz, 100 MHz |
| Channel model | AWGN, CDL-B or CDL-C in TR 38.901 with up to 30ns delay spread |
| UE speed | 3km/h, 0km/h |
| Number of UE antennas | 1T4R, ~~2T4R or 4T4R~~ |
| Number of gNB antennas | 32T32R or 64T64R or 2T or 8T |
| Tx EVM | 0, 2% |
| Rx EVM | 0, 3% |
| MCS | 256 QAM, 1024 QAM  Coding Rate\*: 0.70, 0.75, 0.80, 0.85, 0.90~~, 0.925~~  Other coding rates are not precluded and, if simulated, to be reported by each company |
| DMRS type | DM-RS type 1 |
| Number of DMRS symbols | 1 |
| Number of scheduled RBs | 273 |
| PDSCH mapping | Type A, Start symbol 2, Duration 12 |
| Rank | Rank1, Rank 2, |
| Channel estimation | Realistic channel estimation |
| Metric | Crossover SNR at transition points between 256-QAM and 1024-QAM |
| Note\*: Coding rates are used for 1024QAM, while coding rates for 256QAM are selected from TS38.214 MCS table 2 | |