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

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

**Agenda Item: 8.3.4**

**Source: Moderator (InterDigital, Inc.)**

**Title: Summary #1 of [107-e-NR-R17-IIoT-URLLC-06] on remaining issues on CSI feedback enhancement**

**Document for: Discussion and Decision**

# Introduction

This contribution is to summarize email discussion [107-e-NR-R17-IIoT-URLLC-06] on remaining issue on CSI feedback enhancement. The discussion centers on proposals from one contribution submitted under AI 8.3.4 (Others) related to assumptions on CSI reference resource bandwidth and TBS for subband and wideband CQI calculations, when subband CQI reporting is configured ([2], section 5).

In RAN1#106-e, RAN1 agreed to support 4-bits subband CQI reporting and that RRC can configure use of legacy 2-bits D-CQI or 4-bits CQI for each CSI report configuration, for a UE capable of this feature. In RAN1#106b-e, RAN1 further agreed that wideband CQI is transmitted in a 4-bits subband CQI report. During discussions leading to this agreement, it was clarified that precoder assumptions for wideband CQI and subband CQI are the same [3].

Here is the color code used in this summary:

* FL’s proposals
* Questions for the inputs from companies
* FL summary based on the companies’ input
* RAN1 agreements

# Collection of agreements/conclusion in RAN1 #107-e

To be captured once agreement is made during this meeting.

# Proposals for 1st check point

TBD

# Proposals for final check point

TBD

# Topic #1: Bandwidth of CSI reference resource

## Summary of issues for Topic #1

Contribution [2] quotes the following sections of 38.214:

38.214 section 5.2.2.5 : CSI reference resource

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| The CSI reference resource for a serving cell is defined as follows:  - In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CSI relates.  - In the time domain, the CSI reference resource for a CSI reporting in uplink slot *n'* is defined by a single downlink slot *n*-*nCSI\_ref*,  …………..  If configured to report CQI index, in the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, for deriving PMI and RI:  - The first 2 OFDM symbols are occupied by control signaling.  - The number of PDSCH and DM-RS symbols is equal to 12.  - The same bandwidth part subcarrier spacing configured as for the PDSCH reception  - The bandwidth as configured for the corresponding CQI report. |

38.214 section 5.2.2.1: CQI calculation assumes the CSI reference resource

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| 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  - 0.00001, if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures 'table3' (corresponding to Table 5.2.2.1-4).  ……  For each sub-band index *s,* a 2-bit sub-band differential CQI is defined as:  - Sub-band Offset level (*s*) = sub-band CQI index (*s*) - wideband CQI index.  The mapping from the 2-bit sub-band differential CQI values to the offset level is shown in Table 5.2.2.1-1   * **Table 5.2.2.1-1: Mapping sub-band differential CQI value to offset level**  |  |  | | --- | --- | | **Sub-band differential CQI value** | **Offset level** | | 0 | 0 | | 1 | 1 | | 2 | ≥ 2 | | 3 | ≤-1 |   For each sub-band index *s,* a 2-bit sub-band differential CQI is defined as:  - Sub-band Offset level (*s*) = sub-band CQI index (*s*) - wideband CQI index.  The mapping from the 2-bit sub-band differential CQI values to the offset level is shown in Table 5.2.2.1-1   * **Table 5.2.2.1-1: Mapping sub-band differential CQI value to offset level**  |  |  | | --- | --- | | **Sub-band differential CQI value** | **Offset level** | | 0 | 0 | | 1 | 1 | | 2 | ≥ 2 | | 3 | ≤-1 |   A combination of modulation scheme and transport block size corresponds to a CQI index if:  - the combination could be signaled for transmission on the PDSCH in the CSI reference resource according to the Transport Block Size determination described in Clause 5.1.3.2, and  - the modulation scheme is indicated by the CQI index, and  - the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant. |

According to [2], the specification text highlighted above on “the bandwidth as configured for the corresponding CQI report” could be interpreted in two ways in case the network configures subband CQI reporting:

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| Case 2: gNB has configured SB CQI reporting  Interpretation 1: *bandwidth of SB is used for WB-CQI calculation*  In this interpretation, “*bandwidth as configured for the corresponding CQI report*” refers to the bandwidth of SB as corresponding CQI report is SB-CQI reporting (configured CQI reporting mode). Also, as the WB-CQI reported together with SB-CQI reporting, the bandwidth assumption for WB-CQI may assume the same bandwidth of SB. This means that the assumed TBS for both WB-CQI and SB-CQI calculation is derived from the SB bandwidth, based on the fact that the highlighted section 5.2.2.5 bullet point text refers to a single bandwidth value. *However*, *there is no explicit text in the RAN1 specification to properly support this interpretation*.  Interpretation 2: *entire CSI reporting band for WB-CQI calculation*  In this interpretation, “*bandwidth as configured for the corresponding CQI report*” refers to the bandwidth of SB for SB-CQI and entire CSI reporting band for WB-CQI which is reported with SB-CQI. This may be further clarified as 38.214 has “the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CSI relates” where we can interpret that cases of derived CSI = WB-CQI (BW relates to the entire CSI reporting band) and derived CSI = SB-CQI (BW relates to the sub-band). |

According to [2], the proper understanding is Interpretation 2 and [2] proposes that RAN1 confirms this:

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| **Proposal 3.1.1: RAN1 may further confirm/clarify the assumed CSI reference resource bandwidth for SB/WB CQI calculations when SB-CQI reporting has been configured:**   * **the UE uses two different bandwidth assumptions, one (sub-band bandwidth) for deriving SB CQI indexes and another (entire CSI reporting band) for deriving WB CQI index as part of SB CQI report.** |

Assuming that the above is agreeable, [2] proposes to a modification to the specification to force the same TBS assumption for both subband and wideband CQI indexes, at least for the 2-bits D-CQI case.

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| **Proposal 3.1.2: In sub-band offset level computation, the TBS assumption used for SB CQI index computation shall be used also for WB CQI index computation.**  The specification can be easily enhanced further by letting gNB configure the TBS that UE should use in CQI index computation. To be on the safe side, UE could use the derived TBS assumption (derived according to existing specification) or the gNB configured TBS assumption, whichever is smaller.  **Proposal 3.1.3: gNB can configure the TBS assumption that UE shall use in CQI index computation. UE shall use the derived TBS assumption (derived according to existing specification) or the gNB configured TBS assumption, whichever is smaller.** |

## E-mail discussion (1st round) for Topic #1

**Question 1-1**: Please indicate your interpretation of *bandwidth as configured for the corresponding CQI report* for the wideband CQI, in case the network configures subband CQI reporting. Please also indicate if you think there should be a difference between 2-bits subband D-CQI and 4-bits subband CQI.

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| Company | Interpretation | Comments |
| HW/HiSi |  | We think that the wideband CQI that is reported together with the 4-bit subband CQI should be same as for the legacy 2-bits subband CQI.  For the other part of this question and for the remaining questions, could you please clarify, because we are not sure if Rel-17 URLLC is the proper place to handle them? Isn’t this more related to Rel-15? |
| Intel |  | Note, in past we submitted maintentance tdoc in R1-1910633 regarding similar issue, but it was not eventually agreed. We can at least clarify this for the new 4-bit reporting mode.  We don’t think there is currently a common understanding on Interpretation 1 vs Interpretation 2. In the same time Interpretation 1 is preferred. |
| Apple |  | Rel-17 URLLC CSI feedback enhancement is about replacing 2-bit subband CQI with 4 bit subband CQI, and nothing else. This is not the right venue to open discussion on how CQI is acutally calculated, which can be handled in Rel-16 maintenance session if necessary (we don’t see the point of doing that). |
| DOCOMO |  | We share the same view as HW/HiSi and Apple. Other than replacing 2-bits subband CQI by 4-bits subband CQI, no change is made in Rel-17 URLLC CSI feedback enhancement. The question should be discussed in a proper AI. |
| Lenovo, Motorola Mobility |  | Agree with HW and Apple. In our understanding, wideband CQI is derived based on the entire band irrespective of whether subband CQI is configured or not. |
| OPPO |  | We are told by our MIMO colleague that the current spec has no ambiguity on this matter. To our understanding, WB CQI is certainly associated with entire BW by its definition, regardless how the reporting is configured. Anyhow, we would like to suggest NOT to have a Rel-17 URLLC specific handling from URLLC-CSI session; instead, RAN1 should leave a chance for RAN1 MIMO team to eventually settle on a unified solution across releases, if anything is indeed ambiguous in the whole picture.  For the 2nd question, we think the bandwidth handling should be the same between 2-bits subband D-CQI and 4-bits subband CQI. |
| Nokia/NSB |  | We think that CSI feedback enhancement is not only about extending 4-bit sub-band CQI as associated issues should be clarified. Otherwise, the enhancement is further adding additional ambiguity. From our view, it is good to conclude one interpretation at least for 4-bit SB CQI reporting. |
| LG |  | We share the same view as HW/HiSi and Apple. 4 bit D-CQI is just drop-in replacement of 2 bit CQI so no changes are necessary. |
| QC |  | I have same view as many other companies. The same interpretation as in Rel-15 should be applied, regarding the bandwidth. If there is any ambituity, it should be address in Rel-15/16 maintenance for MIMO. Rel-17 URLLC enhancement is not the correct AI to handle this. |
| MediaTek |  | If there is an ambiguity on the BW used for SB-CQI, then is should be resolved in R15 maintenance. We disagree with;   * having different interpretations for 2-bit and 4-bit SB-CQI reporting, or * clarifying the ambiguity only for the 4-bit SB-CQI.   There is no difference between 2-bit and 4-bit SB-CQI calculations, it is only the quantization for the report that is changed in R17. |
| ZTE |  | Regarding the bandwidth, we think the entire CSI reporting band is used for WB CQI regardless of the CQI mode. There is no ambiguity in the spec.  We share the same view with the other companies. The change other than 2 bit CQI replaced by 4 bit CQI for sub-band is not necessary. |

**Question 1-2**: Please indicate if you think the specification needs to be updated to clarify the interpretation.

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| Company | Yes/No | Comments |
| Intel |  | In past there was similar discussion around tdoc R1-1910633, but nothing was agreed. If the clarification can be made at least for the new 4-bit reporting mode, we see it beneficial. |
| Lenovo, Motorola Mobility | No | Seems LTE specification (TS 36.213) is also written similarly:  “The CSI reference resource for a serving cell is defined as follows:  - For a non-BL/CE UE, in the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates.” |
| OPPO | Not from URLLC session | We suggest to leave the decision to RAN1 MIMO experts in maintenance procedure, which could be per company CR proposal, and propose a conclusion for this meeting like following:  Proposed Conclusion:  *Rel-17 URLLC does not pursue further clarification of interpretation of “wideband CQI bandwidth as configured for the corresponding CQI report”, assuming the same specification clarification handling (either further clarified or not further clarified) to be applied between 2-bits subband D-CQI and 4-bits subband CQI.* |
| Nokia/NSB | Yes | Agree with Intel. |
| QC |  | The issue, if any, should be treated in Rel 15/16 maintenance for MIMO. Rel-17 URLLC enhancement is not the correct AI to handle this. |
| MediaTek |  | If there is an ambiguity on the BW used for SB-CQI, then is should be resolved in R15 maintenance. We disagree with;   * having different interpretations for 2-bit and 4-bit SB-CQI reporting, or * clarifying the ambiguity only for the 4-bit SB-CQI.   There is no difference between 2-bit and 4-bit SB-CQI calculations, it is only the quantization for the report that is changed in R17. |
| ZTE |  | We don’t see the need. Even if needed, it should be discussed in maintenance session since it is common for 2-bit and 4-bit CQI. |

**Question 1-3**: Please indicate if you would agree with Proposal 3.1.2 of [2], i.e. subband CQI index computation and wideband CQI index computation use the same TBS assumption.

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| Company | Yes/No | Comments |
| Intel | Yes | We agree that following Interpretation 1 is more logical. |
| Lenovo, Motorola Mobility | No | Our understanding is different TBSs are used during WB-CQI and SB-CQI derivation. |
| OPPO | No | FL said this proposal is “at least for the 2-bits D-CQI case”. We suppose Rel-17 URLLC session should not change existing specifications determined in earlier release and outside of URLLC scope. |
| Nokia/NSB | Yes | Same arguments provided in our contribution. |
| LG |  | We think it is related to outcome of Question 1-1. |
| QC |  | The issue, if any, should be treated in Rel 15/16 maintenance for MIMO. Rel-17 URLLC enhancement is not the correct AI to handle this. |
| MediaTek |  | If there is an ambiguity on the BW used for SB-CQI, then is should be resolved in R15 maintenance. We disagree with;   * having different interpretations for 2-bit and 4-bit SB-CQI reporting, or * clarifying the ambiguity only for the 4-bit SB-CQI.   There is no difference between 2-bit and 4-bit SB-CQI calculations, it is only the quantization for the report that is changed in R17. |
| ZTE |  | It should follow the legacy behavior. |

**Question 1-4**: Please indicate if you would agree that gNB can configure TBS assumption that the UE shall use for CQI computation (at least in some cases), or if existing specification is sufficient.

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| Company | Yes/No | Comments |
| Intel | No | Configuration is not required. A single assumption would be sufficient. |
| OPPO | No | Existing spec should be sufficient in our view. |
| Nokia/NSB | Yes | Will add further flexibility as URLLC TBS sizes are smaller and CSI feedback assumptions can be aligned with planned TBS for URLLC use cases. |
| LG |  | We think it is related to outcome of Question 1-1. |
| QC | No | The enhancement is not needed |
| MediaTek |  | We agree with the usefulness of such enhancement, but it doesn’t seems it is possible to have consensus at this stage of the WI. |
| ZTE | No | We believe the existing specification is sufficient. |

# References

1. RP-210854 Revised WID: Enhanced IIoT and URLLC support for NR Nokia, Nokia Shanghai Bell.
2. R1-2111141 Discussion on enhancements for PDC and CSI Nokia, Nokia Shanghai Bell.
3. R1-2110509 Feature lead summary #2 on CSI feedback enhancements for enhanced URLLC/IIoT Moderator (InterDigital, Inc.)

# Appendix: Previous agreements on CSI enhancements

RAN1#106b-e

**R1-2110509** Feature lead summary #2 on CSI feedback enhancements for enhanced URLLC/IIoT Moderator (InterDigital, Inc.)

**Agreement**

When subband CQI reporting is configured with 4-bits per subband, UE includes wideband CQI in report.

RAN1#106-e

**Agreement**

For subband CQI reporting with more than 2 bits per subband

* Support 4-bits CQI only

**Agreement**

For subband CQI reporting in Rel-17, RRC can configure use of legacy 2-bits D-CQI or 4-bits CQI for each CSI report configuration.

* This feature is subject to UE capability
* FFS: Whether wideband CQI report can be omitted

**R1-2108450** Feature lead summary #4 on CSI feedback enhancements for enhanced URLLC/IIoT Moderator (InterDigital)

**Conclusion**

There is no consensus in RAN1 on the support of delta-MCS in Rel-17.

Guidance from RAN#92-e

(RP-211297)

RAN1 to further investigate the following for CSI enhancements for IIoT/URLLC:

* Increasing the number of bits used for the reported subband CQI (3-bits differential subband CQI or 4-bits CQI)
* Reporting of delta-MCS:
  + Report consists of delta-MCS for a TB received with MCS index IMCS:

delta-MCS is calculated from the difference between IMCS\_tgt and IMCS, where IMCS\_tgt is the largest MCS index such that the estimated BLER for a TB received with this MCS index would be smaller than or equal to a BLER target, and IMCS is the MCS index of the received TB.

Agreements from RAN1#104b-e

**Conclusion:**

For new reporting Case 1, do not consider further the following schemes:

* Case 1-2: CSI prediction
* Case 1-4: Interference covariance matrix
* Case 1-9: Reference wideband CQI excludes worst sub-bands
* Case 1-10: CSI expiration time

Agreements:

For new reporting Case 2, focus study on reporting of delta-CQI/MCS (Case 2-3):

* Note: this delta-CQI/MCS is determined based on UE implementation (for example, using SINR, LLR, raw BER, flipped bits, LDPC iterations, BLEP, # fail parity checks, etc.)
  + Companies are encouraged to provide more details in their analysis
* FFS: Granularity of new report type (e.g. units of CQI or MCS, how many bits)
* FFS: Whether quantity reported is relative to the scheduled MCS

Agreement: Focus study on the following for new reporting Case 1:

* Reporting of new metric, where new metric shall be determined based on network configured channel and interference measurement interval (multiple CMR and/or IMR instances) to enable accurate MCS selection.
  + Downselect by RAN1#105 to at most a single method from the following options:
    - Mean-CQI/SINR and stdev-CQI/SINR (FFS details)
    - CSI based on worst IMR occasion (FFS details)
    - Interference standard deviation (FFS details)
    - Worst-M CQI (FFS details)
  + FFS: Whether network configured channel and interference measurement interval can also be applied to existing CSI type
* Increasing granularity of subband CQI (e.g. 3-bits differential subband CQI or 4-bits full subband CQI).
* Updating only CQI in a report, where CQI is conditioned on a previous instance in which RI/PMI/(CRI) is updated.
  + Applicable for same reporting quantity as R16 for CQI.
  + FFS: Whether network configured channel and interference measurement interval can also be applied
  + FFS: Whether RI/PMI/(CRI) is transmitted in a report where only CQI is updated
  + ~~FFS: how to report the updated CQI~~
  + FFS: whether the CQI processing time can be ~~is~~ reduced compared to Rel-16 CSI processing delay

Final summary in R1-2103956

Agreements from RAN1#104-e

**[R1-2101811](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_104/Docs/R1-2101811.zip)**

**Conclusion:** Continue evaluation of new reporting Case 1 and Case 2 for the schemes identified in Appendix B of [R1-2102131](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_104/Docs/R1-2102131.zip).

* Companies are encouraged to provide their views on each scheme against each criterion in respective Tables in Appendix B.
* Companies are encouraged to provide additional evaluation results for as many schemes as possible, based on assumptions agreed in RAN1#102-e.
* Aim for down-selection at RAN1#104-b-e by taking into account evaluation results and assessment against criteria from Appendix B.

Agreements from RAN1#103-e:

Agreements

* No change of CSI processing time relative to Rel-16 CSI in this WI
* CSI processing time specific to a new CSI reporting quantity/type (if supported) can be studied

Agreement:

* For Case-2 new reporting, continue studying with focus on the new reporting type based on PDSCH decoding for OLLA performance enhancement for initial and re-transmissions of PDSCH.

Agreements:

For Case-1 New reporting, the following candidate schemes have been identified to address the fast interference change over time. Continue studying with focus on the identified schemes below for further study and evaluation.

* Scheme 1a: New reporting quantity based on CQI/SINR statistics, e.g.,
  + CQI/SINR statistics (e.g., mean, variance, etc.)
  + CSI prediction
* Scheme 1b: New reporting quantity of interference statistics (e.g., mean, variance, interference covariance matrix, etc.)
* Scheme 1c: New reporting quantity based on modifying existing reporting format, e.g.,
  + CQI reporting considering the worst subbands
  + Subband CQI granularity enhancement
* Scheme 1d: New reporting quantity related to CSI expiration time
* Scheme 1e: New reporting quantity with partial information update, e.g.,
  + CSI reporting with interference update only

Companies are encouraged to investigate the above schemes, aiming for down-selection in RAN1#104-e

Agreements from RAN1#102-e:

Agreement:

* CSI feedback enhancement for Multi-TRP transmission is not to be discussed further under IIoT/URLLC enhancement WI

Agreements:

* Baseline assumptions are used as the required minimum to be simulated for the evaluation of candidate CSI enhancement schemes
  + Reuse the assumptions in TR 38.824 and TR 38.901 as a starting point
  + Companies shall report additional parameters (e.g., CSI measurement settings, CSI reporting schemes) used in their evaluation
  + FFS details of baseline assumptions
* Companies can bring additional simulation results with other set(s) of assumptions

Agreements:

* Study/evaluate further on following CSI enhancement schemes in terms of technical benefit, specification and implementation impacts.
  + New triggering methods for A-CSI and/or SRS
  + New reporting based on one or more of the following:
    - Case 1: channel/interference measurement for new CSI reporting, considering aspects such as one or more of the following:
      * Reporting more accurate interference characteristics
      * Reduced CSI feedback overhead (e.g., reporting interference measurement only)
      * Enhanced CSI reporting such as WB/SB CQI
    - Case 2: other measurement (other than channel/interference) for additional information
      * E.g., PDCCH/PDSCH decoding, recommended HARQ RV sequence, etc.
    - It targets to help gNB scheduler for better link adaptation of (re)transmission
  + [Reduced CSI computation time/complexity]
  + [CSI feedback for PDCCH]
  + Other CSI enhancement schemes that enable accurate MCS selection are not precluded
* Detailed assumptions of the proposed CSI enhancement schemes should be provided by the proponent, such as
  + Reporting values
  + Triggering conditions for the reporting
  + Associated measurement resource
  + Uplink resource to be used for the reporting
  + How to use the reported information at the gNB scheduler
  + CSI-RS overhead and CSI reporting frequency
  + CSI reporting latency/timeline
  + Etc.

Agreements:

* Consider Table 1 as baseline assumption for system level simulation for evaluating CSI enhancement schemes
  + The uses cases in Table 1 is for simulation purposes and it does not preclude a CSI enhancement scheme which is beneficial for the other URLLC use cases
* No baseline assumption is used for link level simulation
  + Companies are encouraged to use one of LLS assumption tables in Section A.3 in TR38.824 for any link level simulation

**Table 1. Baseline SLS assumption for CSI enhancement schemes in URLLC/IIoT**

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| --- | --- |
| **Parameters** | **Values** |
| Performance metric | Option-1 (section 5.1 of TR 38.824)  Additional metrics (it is up to company to bring results with additional metric):   * MCS prediction error (e.g., difference of a scheduled MCS and an ideal MCS) * DL/UL signaling overhead * CCDF of latency samples from all UEs * BLER of 1st transmission * Resource utilization * Spectral efficiency |
| Use cases | Following two use cases can be considered for new triggering method and new reporting. Companies are encouraged to evaluate the following cases in descending priority:   * Rel-15 enabled use case (e.g. AR/VR) in TR 38.824   + Reliability: 99.999   + Latency: 4ms (200bytes)   + Traffic mode: FTP model 3 (100p/s) * Factory automation in TR 38.824   + Reliability: 99.9999   + Latency: 1ms (32bytes)   + Traffic mode: Periodic deterministic traffic model with arrival interval 2ms * Rel-15 enabled use case (e.g. AR/VR) in TR 38.824   + Reliability: 99.999   + Latency: 1ms (32bytes)   + Traffic mode: FTP model 3 (100p/s)   + Assumptions for eMBB and URLLC UEs sharing the same carrier is used (as in A2.5 of TR 38.824) |
| Simulation assumptions | Following simulation assumption is used based on the use case selected:   * Rel-15 enabled use case with UMa (Table A.2.4-1 in TR 38.824) * Factory automation at 4GHz (Table A.2.2-1 in TR38.824) with following update:   + Channel model is replaced with InF (InF-DH) in TR 38.901     - Companies can bring results with other InF scenarios additionally   + Layout is replaced with BS deployment in Table 7.8-7 in TR 38.901 |
| Transmission scheme | Multiple antenna ports Tx scheme   * Companies report the details of Tx scheme used |