**3GPP TSG RAN WG1 #106-e R1-21xxxxx**

**e-Meeting, August 16th – 27th, 2021**

**Agenda Item: 8.3.1.2**

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

**Title: [Draft] Feature lead summary #2 on CSI feedback enhancements for enhanced URLLC/IIoT**

**Document for: Discussion and Decision**

# Introduction

This contribution is a summary of contributions [2]-[24] submitted under AI 8.3.1.2 (CSI feedback enhancements) The AI is related to the following objective of the revised work item on Enhanced IIoT and URLLC support for NR [1]:

|  |
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| 1. Study, identify and specify if needed, required Physical Layer feedback enhancements for meeting URLLC requirements covering    * + UE feedback enhancements for HARQ-ACK [RAN1]      + CSI feedback enhancements to allow for more accurate MCS selection [RAN1]   Note: DMRS-based CSI feedback is not in scope of this WI |

In RAN1#102-bis-e and subsequent RAN1 meetings, RAN1 studied a set of CSI enhancement schemes in terms of technical benefits, specification and implementation impacts. The candidate enhancement schemes included new triggering methods for A-CSI and/or SRS, new reporting based on channel/interference measurement (Case 1), and new reporting based on other measurement (Case 2).

As of RAN1#105-e, RAN1 had not reached agreement on which scheme(s) are to be supported. In RAN#92-e, RAN provided guidance to focus on schemes proposed in RP-211297 [25]. More specifically, the schemes consist of the following:

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| 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. |

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 #106-e

To be captured once agreement is made during this meeting

# Proposals for 1st check point

TBD

# Proposals for 2nd check point

TBD

# Proposals for 3rd check point

TBD

# Proposals for 4th check point

TBD

# Topic #1: Increasing number of bits for subband CQI report

In this section, we provide summary of contributions discussing candidate enhancement schemes involving increasing number of bits for subband CQI report.

## Evaluation results

Contributions from ZTE [6], Samsung [9], InterDigital [12], Futurewei [13], Mediatek [19], Intel [20] and ITRI [23] present evaluation results for subband CQI report with increased number of bits. The results are summarized in following Table:

|  |  |  |  |
| --- | --- | --- | --- |
| ZTE [6] | 3-bits D-CQI or 4-bits? | AR/VR  (40 UEs /cell) | 85.7% [86.7%] satisfied UEs  4.3 RU [4.3 RU] |
| Samsung [9] | 3-bits D-CQI | ??? | 0.2%, 1.9%, 1.0% gain for average/median/5 pctile throughput respectively. |
| Samsung [9] | 4-bits full CQI | ??? | 0.5%, 0.7%, 15.6% gain for average/median/5 pctile throughput respectively |
| InterDigital [12] | 3-bits D-CQI | AR/VR (20 UEs /cell) | 95.6% [93.6%] satisfied UEs  8.0 RU [7.7 RU] |
| InterDigital [12] | 4-bits full CQI | AR/VR (20 UEs /cell) | 95.6% [93.6%] satisfied UEs  8.0 RU [7.7 RU] |
| InterDigital [12] | 3-bits D-CQI | Factory (30 UEs /cell) | 94.6% [92.0%] satisfied UEs  6.7 RU [6.6 RU] |
| InterDigital [12] | 4-bits full CQI | Factory (30 UEs /cell) | 94.6% [92.0%] satisfied UEs  6.8 RU [6.6 RU] |
| Futurewei [13] | 4-bits full CQI | AR/VR  (20 UEs /cell) | 76.4% [48.2%] satisfied UEs  31% [71%] RU |
| Mediatek [19] | 3-bits D-CQI | Factory | 21.2% RU (25.1%) |
| Mediatek [19] | 4-bits full CQI | Factory | 21.2% RU (25.1%) |
| Intel [20] | 4-bits full CQI | Factory | 21% [25%] satisfied UEs |
| ITRI [23] | 3-bits D-CQI | Factory | 87.2% [63.3%] satisfied UEs  7.0% [6.3%] RU |
| ITRI [23] | 4-bits full CQI | Factory | 90.6% [63.3%] satisfied UEs  7.1% [6.3%] RU |

## Summary of issues for Topic #1

Most contributions discuss increasing number of bits for better accuracy of subband CQI.

**Issue #1-1: Support reporting with increased number of bits for subband CQI?**

Yes: Huawei [2], Vivo [3], Ericsson [4], Spreadtrum [5], Sony [7], Quectel [8], Samsung [9], Nokia [11], InterDigital [12], Futurewei [13], Qualcomm [16], LG [18], Mediatek [19], ITRI [23]

* Gains can be observed in evaluations [9][12][13][19][23], e.g. higher accuracy, higher % of satisfied UEs and reduced resource utilization.

Maybe: Lenovo [14], Intel [20], NTT DoCoMo [22]

* Little/no gain observed from evaluations from past [14][22] or current [20] meeting. Further evaluations are needed [14][20][22].
* Extended SINR range of legacy CQI table should also be supported [20]

No: CATT [10]

* Little/no gain observed from (past) evaluations

Within the contributions proposing increased number of bits for subband CQI, the following schemes are proposed:

**Issue #1-2: Proposed scheme for increased number of bits for subband CQI**

* **3-bits D-CQI format (with fixed values)**: Vivo [3], Spreadtrum [5], Sony [7], Quectel [8], Samsung [9], InterDigital [12], Qualcomm [16], Mediatek [19], ITRI [23]
  + Natural extension from 2-bits D-CQI [3][16]
  + Less overhead than 4-bits CQI
  + Most or all of the potential gain achieved with 3-bits [12][23]
* **4-bits CQI**: Huawei [2], Vivo [3], Spreadtrum [5], Sony [7], Quectel [8], Samsung [9], Nokia [11], Futurewei [13]
  + Provides full CQI report resolution [2]
  + Less specification effort than 3-bits D-CQI [2]
  + May not require WB-CQI as reference [2]
* **D-CQI with range and resolution indicator (RRI)**: Ericsson [4]
  + Provides reporting flexibility and granularity without excessive overhead [4]

Several contributions [2][3][7][8][9] propose that RRC can configure the subband granularity between legacy, 3-bits D-CQI or 4-bits CQI. This allows control of overhead by network.

Several contributions [8][11][18] propose enhancements that could limit the additional overhead compared to using a 3-bits D-CQI table or 4-bits CQI for all subbands, while still potentially bringing benefit from additional accuracy:

* Configure number of bits on subband basis [8]
  + Limit additional overhead when interference is expected to be low in certain subbands
* Support option where UE reports CQI from worst subbands only [11]
* Introduce indication of whether increased granularity is utilized in CSI part 1 [18]

**Observations on increasing number of bits for subband CQI report.**

Most of the evaluations available from the contributions submitted at this meeting show the potential performance gain of increasing the number of bits of subband CQI [9][12][13][19][23]. Two evaluations [6][20] do not find a gain. Because scheduler behaviour is not part of the assumptions, such discrepancies can be expected.

The contributions indicate that a strong majority of companies support introduction of subband CQI with increased number of bits. About half of companies prefer 3-bits D-CQI and half prefer 4-bits CQI. Several companies also propose that the network could decide to configure one or the other depending on whether UL overhead or accuracy is more important in a given scenario. In view of this, it is proposed to agree on the following:

**FL proposal 7.2-1:**

**Support at least the following schemes:**

* **3-bits differential subband CQI** 
  + **Adopt following mapping as baseline: {0,1,2,>=3,-1,-2,-3,<=-4}**
  + **FFS: Use of different mapping in place of the above**
* **4-bits subband CQI**
* **FFS: Additional schemes**

**RRC can configure use of wideband CQI, legacy 2-bits D-CQI or one of the above schemes for each CSI report configuration.**

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

**Question 1-1**: Please provide feedback if you would like to either (a) make correction in this moderator summary (Topic #1) or (b) add your company position

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| Company | Yes/No | Comments |
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**Question 1-2**: Please indicate if FL proposal 7.1-1 is acceptable

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| Company | Yes/No | Comments |
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# Topic #2: Delta-MCS

In this section, we provide summary of contributions discussing Delta-MCS reporting.

## Evaluation results

Contributions from ZTE [6], InterDigital [12], Futurewei [13], Qualcomm [16] and Intel [20] present evaluation results for Delta-MCS. The results are summarized in following Table:

|  |  |  |  |
| --- | --- | --- | --- |
| ZTE [6] | Delta-MCS | AR/VR | 94.8% satisfied UEs [86.7%]  8.1% RU [4.3%] |
| InterDigital [12] | Delta-MCS | Factory | 100% satisfied UEs [99%]  5.0 RU [4.8] |
| InterDigital [25] | Delta-MCS | Factory | 72.4% satisfied UEs [54.3%]  4.1 RU [4.1]  (bias reset every 300 ms) |
| Futurewei [13] | Delta-MCS | AR/VR | 25.3% satisfied UEs [48.2%]  93% RU [71%] |
| Qualcomm [16] | Delta-MCS | AR/VR (mixed traffic, 20 URLLC UEs) | 100% satisfied UEs [100%]  930 RBs for 2nd Tx [1445] |
| Qualcomm [16] | Delta-MCS | AR/VR (mixed traffic, 100 URLLC UEs) | 100% satisfied UEs [100%]  5878 RBs for 2nd Tx [7545] |
| Intel [20] | Delta-MCS | Factory | 20% [25%] satisfied UEs |

## Summary of issues for Topic #2

The most important issue is obviously whether Delta-MCS should be supported. Views from contributions are summarized as follows.

**Issue #2-1**: Support Delta-MCS reporting?

Yes: (Ericsson [4]), Spreadtrum [5], ZTE [6], Sony [7], Quectel [8], Samsung [9], CATT [10], Nokia [11], InterDigital [12], Lenovo [14], Oppo [15], Qualcomm [16], CMCC [17], LG [18], NTT DoCoMo [22]

* Direct way to feedback decoding margin [5]
* Can provide exact channel state more frequently and timely, efficient scheduling, Robust to channel variation and bursty interference [6][16]
* Enhance OLLA operation [10][22]
* Legacy OLLA not feasible solution for URLLC [11][15]. Normal link adaptation cannot track fading/interference fast enough [16]. Unpractical to set step size of NACK 9999 times of ACK otherwise MCS is always 0 [16].
* CQI not available in time for retransmission, information from PDSCH decoding does not require extra computation [15]
* Better capability of target BLER tracking than baseline [15]
* Avoids excessive SNR backoff for retransmission [16]

Maybe: Huawei [2]

* Only if A-CSI on PUCCH is supported

No: Vivo [3], Futurewei [13], Mediatek [19], Intel [20]

* Only useful if retransmission is in same resource (scheduler flexibility), Delta-MCS does not provide information on future interference [3][13]
* BLER target applied at gNB may be different from BLER target assumed by UE [3]
* No evident performance gains [3][20]
* Less efficient than periodic/aperiodic CSI report [3], no need for periodic data traffic [19]
* Non-trivial spec impact (reporting resource and channel, how to trigger, impact on HARQ codebook, whether to report for every PDSCH, handling for multiple PDSCHs, testability) [3][20]
* Similar to A-CSI on PUCCH if for retransmission, wasted power consumption [19]
* Large overhead/reliability loss to add for every ACK position in codebook, impacts processing timeline, possible ambiguity if report is conditional [19]

Contributions also provide views and alternatives on the following issues related to support of Delta-MCS:

**Issue #2-2:** Resource for transmission of the Delta-MCS report

* **In same resource as HARQ-ACK (extended HARQ-ACK codebook or appended to HARQ-ACK)**
  + Yes: Ericsson [4] (not Type-3), Spreadtrum [5], ZTE [6], Quectel [8], Samsung [9], Nokia [11], InterDigital [12], Lenovo [14], Oppo [15], Qualcomm [16], LG [18] (not for all HARQ-ACK), Apple [21], NTT DoCoMo [22] (not Type-1)
    - No need for extra timing or resource indication [4]
    - Ensures timely reporting for HARQ Retx [6][11][15]
    - HARQ-ACK and Delta-MCS can be jointly encoded [4][9]
* **In PUCCH resource separate from HARQ-ACK**:
  + Yes: Huawei [2]?, LG [18], (NTT DoCoMo [22]), (Ericsson [4])
    - Can use A-CSI on PUCCH [2][22]
    - On next available periodic PUCCH [18]
  + No: Quectel [8], Samsung [9]
    - High specification impact, e.g. determining PUCCH resource, overlapping, coding UCI multiplexing, dropping [8][9] need to identify reference PDSCH [14][15]
    - Smaller encoding gain compared to joint coding with HARQ-ACK [9]
    - May not be feasible for TDD [9]
    - (Would increase DCI overhead) [10]
    - Increased uplink overhead due to transmission in different resource[15]
* **In MAC CE**: InterDigital [12]
  + Delta-MCS for OLLA does not require urgent transmission, can use averaging [12]

**Issue #2-3**: What target BLER is assumed by UE for calculating Delta-MCS?

* Single fixed value [21]
  + Ease UE implementation burden [21]
* Support only two values {1e-1;1e-5} [15]
  + Supporting arbitrary target BLER values increases UE implementation complexity [15]
* More than two values possible [4]
  + gNB may want to target values in between, difficult to infer from different target BLER [4]

**Issue #2-4**: How to indicate the target BLER value to UE?

* Semi-static configuration [4][15][22]
  + Per SPS config [7]([11])
  + Per serving cell [15]
* Tied to MCS Table used for the TB [9]([11])[12][14]
  + Since low-SE MCS Table target low BLER
* Indication in DCI (existing or new field) [7]([11])[15]
  + MCS-RNTI for DG [7]([11])
  + Priority index [15]
  + NDI toggling [15]
* Depends on ACK or NACK status of TB [15]

Possible conditions or triggers for reporting Delta-MCS are proposed or mentioned in contributions. Some contributions also suggest to consider reporting of Delta-MCS that is a function of multiple received TBs.

**Issue #2-5**: Possible conditions for reporting delta-MCS for a received TBs

* For single codeword case only [4]
* SPS PDSCH only [4]
* Dynamically indicated [5]([10])
* Trigger by (last) DL DCI, or enabled by RRC/MAC CE [6]([10])
* For certain HARQ processes ([8],[10])
* Time window, e.g. within HARQ feedback window [10]
* For certain PHY priority ([11])[12]
* Configured TBS/MCS threshold ([11])
* If the number of PDSCH REs is large enough [14]
* For certain counter DAI values only [15]

**Issue #2-6**: Whether to support single Delta-MCS that is function of Delta-MCSs of multiple received TBs

* Study multiple PDSCH to one delta-MCS [5][7][18]
  + Reduces accuracy: Lenovo [14]
* Reporting may be per CC/serving cell [10][15]
* Grouping by subband [15]

Contributions also discuss the number of bits of a Delta-MCS for a TB and mapping to Delta-MCS values.

**Issue #2-7**: Number of bits for Delta-MCS of a TB (excluding HARQ-ACK)

* 1 bit: Ericsson [4], Nokia [11], InterDigital [12], Qualcomm [16]
  + May consist of 2-bits joint HARQ-ACK/Delta-MCS [4]
* 2 bits: Ericsson [4]
* 2 bits or more: CATT [10]
* Configurable (e.g. 1, 2 or 3 bits): ZTE [6], Samsung [9]

For the mapping to Delta-MCS codepoint to Delta-MCS values, the following aspects are addressed:

**Issue #2-8**: Mapping Delta-MCS values to Delta-MCS codepoints

* RRC configures granularity: Samsung [9]
* May depend on MCS reference: Oppo [15]
* Both positive and negative delta-MCS should be mapped in case of ACK [4]
* Whether an MCS index offset should be configurable?
  + Yes: Huawei [2]
  + No: Samsung [9], InterDigital [12]

**Issue #2-9:** Delta-MCS calculation with PDSCH that carries retransmitted TB

* Whether calculation should take into account soft-combining gain [4][21]
* Whether PDSCH of retransmission or initial transmission is used as reference resource [4]
* Whether MCS used as reference is MCS of retransmission or effective MCS from combining [4]
* Which MCS table to use as reference [4]
* Calculate MCS index closest to corresponding code rate in case MCS index is 29, 30 or 31 [15]

**Other issues / proposals**

* TB size assumption for delta-MCS calculation is same size as received TB [6][9][21]
* Frequence allocation assumption is same as current PDSCH [21]
* From testing perspective, UE is not required to meet the BLER target if a set of suitable conditions are not met [21]: same transmission parameters for the retransmission, CBGTI consistent with UE feedback, etc.
* Consider additional UE processing time (d3) for lower capability UE when Delta-MCS is calculated [4]
* Do no support/consider multi-TRP operation [4]
* Use Delta-CQI with CQI from latest CSI-RS as reference [2]. *Moderator’s note: this seems precluded by RAN guidance.*
* No need to define estimated BLER of a TB in terms of probability estimate of a code block within a TB [9]
* Single Delta-MCS is reported for whole TB even in case of CBG [4]
* Need to address priority between Delta-MCS and other UCI [18]

**Observations on Delta-MCS**

Observations on system-level evaluations

For the decision on whether to support Delta-MCS or not, RAN1 could not make agreement at the previous meeting because of concerns that it would not bring sufficient benefits. At this meeting, 5 companies provided system-level evaluation results in this meeting. 3 companies (ZTE, InterDigital, Qualcomm) identify a performance gain while 2 companies (Futurewei, Intel) obtain a performance loss. Although multiple factors may explain the discrepancies (e.g. differences in scenario/traffic/CSI reporting configuration assumptions), it is likely that a major reason is that the scheduler is modeled differently between the different companies, including OLLA operation and related parameters.

Another question is whether the simulation methodology is entirely appropriate to assess the potential benefits of Delta-MCS. For example, one potential benefit for Delta-MCS is to improve convergence time of OLLA when BLER target is very low. Fast convergence time is important to adapt to variations in channel and/or interference statistics (e.g. average and standard deviation) that may change over time due to mobility and traffic variations over larger time scales. Current simulation assumptions model very well short-term channel and interference variations but perhaps not as well the longer-term variations due to these effects that occur in real-life scenarios. On the other hand, when it comes to the potential benefit of providing guidance on appropriate MCS for retransmission, the simulation methodology seems adequate.

Overall, because of the differing evaluation results and possible inherent limitations of current system-level simulation methodology for capturing all potential benefits of this functionality, it seems difficult to make decision that would be based only on the available evaluation results. Other aspects that could be considered include for example analysis of convergence performance such as illustrated in [15] or [25].

Design aspects

If RAN1 agrees to support Delta-MCS reporting defined as per RAN guidance, a number of issues need to be discussed. The definition used in RAN guidance is as follows:

*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.*

From this definition one identifies the following issues which are discussed in contributions.

* (2.2) Resource for transmission of the delta-MCS report
* (2.3, 2.4) Applicable BLER target
* (2.5, 2.6) Reporting of Delta-MCS as a function of received TBs
* (2.7, 2.8) Mapping between delta-MCS value and difference between *IMCS\_tgt and IMCS*
* (2.9) Delta-MCS calculation with PDSCH that carries retransmitted TB

On the resource (2.2), majority view is that Delta-MCS should be transmitted in same resource as HARQ-ACK as it ensures timely reporting and avoids the problem of provisioning an additional resource.

**FL proposal 8.2-1:**

**Delta-MCS (if supported) is reported in same resource as HARQ-ACK**

* **FFS: Whether HARQ-ACK and Delta-MCS for a TB can be jointly encoded (multi-bit HARQ-ACK)**

On the BLER target (2.3, 2.4), some companies have concern that requiring the UE to perform estimation for arbitrary values may be challenging for implementation, while other companies have concern that the information provided to the network may be difficult to use if the network wants to operate at a different target BLER than used by the UE. As a starting point, moderator suggestion is to agree on supporting at least two values. For the selection of value applicable to a TB, 3 companies proposed to make association with MCS table, in line with the motivation of introducing additional MCS table for URLLC in R15.

**FL proposal 8.2-2**

**For the target BLER applicable to Delta-MCS calculation (if supported)**

* **Support values {1e-1;1e-5}**
  + **FFS: additional values**
* **Target BLER depends at least on MCS table used for the TB**
  + **FFS: whether value for each MCS table is fixed or configured by RRC**

On the number of bits for Delta-MCS (2.7), 4 companies think that the case of 1 bit should be supported and 2 companies would support configurable number of bits for Delta-MCS that would include 1 bit as an option. From this the following is proposed:

**FL proposal 8.2-3**

**For Delta-MCS report (if supported), at least the case of 1 bit per TB (in addition to HARQ-ACK) is supported.**

* **FFS: More than 1 bit**

## E-mail discussion (1st round) for Topic #2

**Question 2-1**: Please provide feedback if you would like to either (a) make correction in this moderator summary for your company position (Topic #2) or (b) add your company position

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| Company | Yes/No | Comments |
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**Question 2-2**: Please indicate any comment or clarification question on evaluation results from another company.

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| --- | --- |
| Company | Comments/questions |
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**Question 2-3**: Please indicate if you agree with the observations on Delta-MCS evaluations in previous section, and if you have any other observations.

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| Company | Yes/No | Comments |
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**Question 2-4**: Based on the observations and considering that large majority of companies support it, can we agree now on supporting Delta-MCS? If not, what should be the next step (e.g. additional evaluation or no support for R17).

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| Company | Yes/No | Comments |
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**Question 2-5**: Please indicate if FL proposal 8.2-1 is acceptable.

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**Question 2-6**: Please indicate if FL proposal 8.2-2 is acceptable.

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| Company | Yes/No | Comments |
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**Question 2-7**: Please indicate if FL proposal 8.2-3 is acceptable.

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| Company | Yes/No | Comments |
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# Topic #3: Other

Contributions discuss enhancements that do not fall in one of the above categories.

## Summary of issues for Topic #3

**Issue #3.1**: Support A-CSI on PUCCH

Yes : Huawei [2], NTT DoCoMo [22]

* No extra PDCCH blind decoding, available number of CCEs for chest, independent successful reception of DL, latency increase for CSI, increase of DL overhead
* Design details [22]
  + New field in DL DCI (formats 1\_1/1\_2) to trigger A-CSI on PUCCH
  + DCI indicates one of a set of resources configured by RRC
  + DCI indicates PHY priority level
  + Multiplex on first actual PUSCH repetition

No: Quectel [8], LG[18]

* Already discussed, no time
* SP-CSI also works [18]

Other issues

* Associate MCS table with priority indicator field value in DCI: Samsung [9]
* Decouple binding between CQI table and target BLER [17]
* Per-serving cell configuration of target BLER [17]

## E-mail discussion (1st round) for Topic #3

TBD

# References

1. RP-210854 Revised WID: Enhanced IIoT and URLLC support for NR, Nokia, Nokia Shanghai Bell.
2. R1-2106491 CSI feedback enhancements Huawei, HiSilicon
3. R1-2106587 CSI feedback enhancements for Rel-17 URLLC vivo
4. R1-2106679 CSI Feedback Enhancements for IIoT/URLLC Ericsson
5. R1-2106698 Discussion on CSI feedback enhancements Spreadtrum Communications
6. R1-2106735 Discussion on CSI feedback enhancements for eURLLC ZTE
7. R1-2106802 Considerations on CSI enhancements for URLLC Sony
8. R1-2106837 Discussion on CSI Feedback Enhancements Quectel, Langbo
9. R1-2106880 UE Feedback Enhancements for URLLC Samsung
10. R1-2106963 CSI feedback enhancements CATT
11. R1-2107019 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
12. R1-2107074 CSI feedback enhancements InterDigital, Inc.
13. R1-2107078 CSI feedback enhancements for URLLC FUTUREWEI
14. R1-2107185 CSI feedback enhancements for URLLC/IIoT Lenovo, Motorola Mobility
15. R1-2107273 CSI feedback enhancements for URLLC OPPO
16. R1-2107337 CSI enhancement for IOT and URLLC Qualcomm Incorporated
17. R1-2107398 Discussion on CSI feeback enhancements for URLLC CMCC
18. R1-2107444 Discussion on CSI feedback enhancements for URLLC LG Electronics
19. R1-2107492 CSI feedback enhancements for URLLC MediaTek Inc.
20. R1-2107584 On enhanced SB CQI reporting granularity and delta-MCS reporting Intel Corporation
21. R1-2107733 CSI feedback enhancements for URLLC Apple
22. R1-2107852 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
23. R1-2108012 Views for Increasing Granularity of Subband CQI ITRI
24. R1-2108237 CSI feedback enhancements InterDigital, Inc.
25. RP-211297 Way forward on CSI feedback enhancements for enhanced URLLC/IIoT InterDigital, Inc., Ericsson, Motorola Mobility, OPPO, Qualcomm, Samsung, SONY, Spreadtrum.

# Appendix: Previous agreements

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**

|  |  |
| --- | --- |
| **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 |