**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]:

|  |
| --- |
| 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:

|  |
| --- |
| 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 UEs4.3 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 UEs8.0 RU [7.7 RU] |
| InterDigital [12] | 4-bits full CQI | AR/VR (20 UEs /cell) | 95.6% [93.6%] satisfied UEs8.0 RU [7.7 RU] |
| InterDigital [12] | 3-bits D-CQI | Factory (30 UEs /cell) | 94.6% [92.0%] satisfied UEs6.7 RU [6.6 RU] |
| InterDigital [12] | 4-bits full CQI | Factory (30 UEs /cell) | 94.6% [92.0%] satisfied UEs6.8 RU [6.6 RU] |
| Futurewei [13] | 4-bits full CQI | AR/VR(20 UEs /cell) | 76.4% [48.2%] satisfied UEs31% [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 UEs7.0% [6.3%] RU |
| ITRI [23] | 4-bits full CQI | Factory | 90.6% [63.3%] satisfied UEs7.1% [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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia/NSB | No |  |
|  |  |  |
|  |  |  |

**Question 1-2**: Please indicate if FL proposal 7.1-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia/NSB | Yes | “Adopt following mapping as baseline: {0,1,2,>=3,-1,-2,-3,<=-4}” is not fully clear to us. What is this trying to explain.  |
| HW/HiSi | Yes | Similar to Nokia, we also think that {0,1,2,>=3,-1,-2,-3,<=-4}could be clarified and we are not sure if the 2 FFSs are needed. But we are ok to accept them for the sake of progress.  |
| Intel | No | We think that it is premature to jump to this kind of details such as agreeing directly the offsets, etc.We observe that simple increase of the signaling to 3 or 4 bits does not provide sufficient mechanisms for gNB to predict SINR distribution seen at the UE. Additional handling of very low or very high SINR is essential to give the accurate information to gNB. For that purpose, we suggest using resulting CQI ranges < 0 and > 15, as well as discuss how to interpret “out of range” CQI=0.Having said that, the following modification would be fine with us:**FL proposal 7.2-1:** **Support at least the following schemes:*** **3-bits differential subband CQI**
	+ **FFS differential sub-band CQI mapping to sub-band CQI offsets**
	+ **~~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: handling and interpretation of WB CQI for 4-bit SB CQI**
* **FFS: handling and interpretation of “out of range” CQI including support of (WB CQI – SB CQI offset) < 0 and (WB CQI – SB CQI offset) > 15**
* **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.** |
| Sony | Yes | Firstly Proposal 7.1-1 does not exists. However, we are fine with Proposal 7.2-1 and to make it more palatable for others perhaps we can discuss the differential CQI mapping for 3 bits option after this agreement. That is on for the 3 bits bullet point, we propose the following:* **3-bits differential subband CQI**
	+ **FFS: the different CQI mapping**
 |
| Futurewei | Yes | We are in general ok with the proposal. Fine with Sony’s revision. |
| Samsung | Yes | Fine with the update from Sony. |
| Apple |  | It is very important to clarify the condition of operating sub-band CQI with 4 bits or 3 bits. If frequency selective fading/interference is assumed, and they are assumed to be consistent/persistent across time (from feedback time to PDSCH reception), that assumption should be clarified. Note this is also related to the discussion on delta-MCS, the interference assumption should also be clarified. |
| Ericsson | No | * First, we do not see any performance justification to accept 4-bit subband CQI. Based on the simulation results submitted to this meeting, most companies’ observed that 4-bit subband CQI brings no or negligible performance improvement compared to 3-bit subband CQI, for example, Samsung [9], InterDigital [12], Mediatek [19], Intel [20]. Considering the substantially higher overhead, we definitely cannot accept 4-bit subband CQI.
* Second, for 3-bit subband CQI, three companies (ZTE [6], Samsung [9], InterDigital [12],) shows negligible/marginal gain compared to 2-bit baseline, while two companies (Mediatek [19], ITRI [23]) shows noticeable gain compared to 2-bit baseline. In our view, this is not convincing to introduce 3-bit subband CQI, since it increases the subband CQI reporting overhead by 50%.

In summary, we don’t think RAN1 should rush to adopt the method of improved subband CQI granularity. RAN1 should investigate further the cost and benefit before adoption. Even if the method is justified, schemes that improves the subband CQI range and granularity, but minimizes overhead, should be preferred, for example, Alternative 1 in Ericsson [4].  |

# 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])
* For certain CCs ([21])
* 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]
* Calculate Delt-MCS considering TCI state, # of spatial layers, PRB bundling, etc. [21]

**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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia | Yes |  |
|  |  |  |
|  |  |  |

**Question 2-2**: Please indicate any comment or clarification question on evaluation results from another company.

|  |  |
| --- | --- |
| Company | Comments/questions |
|  |  |
|  |  |
|  |  |

**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.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Intel |  | We observe that as in prior meetings, this meeting the results provided by companies are **far from justifying the huge spec changes**.* 2 sources provide gains in the target metric (% satisfied UEs)
* 2 sources provide losses in the target metric (% satisfied UEs)
* 1source provides no gain in the target metric, but provides gains in RU of 2nd TX, which translates to ~2 % total RU gain assuming even relatively high initial TX target BLER of 1 %

Overall, it is highly uncertain in which conditions which gains (or losses) can be achieved. |
|  |  |  |
|  |  |  |

**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).

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia |  | We shall discuss the details releated to delta-MCS prior concluding that it can be supported. Conditionally agreeing (‘if supported”) on details will allow companies to simulate delta-MCS with a common framework and see the gains/issues of the scheme.  |
| HW/HiSi | No | If delta-MCS should be supported, the design principles associated with it should be agreed firstly. If this scheme is introduced, it is critical that it can be employed in a meaningful way. Therefore, if delta-MCS is introduced, it should have a low UL overhead, it should not impact the performance of HARQ-ACK and it should not restrict the scheduling flexibility. We are reluctant to support delta-MCS without having agreed on its design details firstly.To ensure a low UL overhead and at the same time to allow the gNB to schedule a TB with a flexible BLER target, either the TB’s BLER target be known at the UE. Additionally, the HARQ-ACK performance should not be degraded. To avoid this, the delta-MCS report could be sent on a separate PUCCH. Or, if the HARQ-A/N and delta-MCS are sent on the same PUCCH, the gNB should have the possibility to choose (i.e. to trigger), when it wants to receive a delta-MCS report. Otherwise, there could come situations where the increased payload results into a loss of reliability of the HARQ.ACK.  |
| Intel | No | We suggest to select only one of Case-1 or Case-2 schemes to move forward. Among the two, Case-1 (enh SB-CQI) has no concerns and has much clearer spec impact, while Case-2 (delta-MCS) has quite high spec effort -to- system gain ratio, which should be avoided. |
| Sony | Yes | On HW’s point about flexible BLER target, the UE does not need to know the BLER target of the scheduled TB in order to calculate Delta-MCS. So it isn’t clear why this is an issue. [Hw/HiSi]. This is the reason why we would like that different characteristics are discussued together, i.e. that design choices can be avoided that would risk to turn out into an inefficient feature. It is true as you said that in principle the UE does not need to know the BLER target of the scheduled TB, the delta-MCS could be calculated for some reference BLER. But this could result into a large required UL overhead since the gNB might use another BLER when scheduling the TB. In this situation, there would be a MCS offset between the MCS obtained at the UE side and the MCS used for scheduling the TB. If the group would then agree to use the MCS of the scheduled MCS as the reference for the delta-MCS report, then there would be many bits required to represent the “delta”. For example, depending on the size of the MCS offset, a delta-MCS=7 could mean “go down with MCS” and a delta MCS=9 could mean go up with the MCS. I hope that this clarifies the issue. |
| Futurewei | No | We shared the same view as Intel that only one of Case 1 or Case 2 schemes should be supported. Based on our evaluation results, Case 1 scheme provides much better performance than delta-MCS scheme. Furthermore, Case 1 scheme has much less spec impact. Therefore, Case 1 scheme should be supported and delta-MCS scheme should not be supported. |
| Samsung | Yes |  |
| Apple |  | The testability issue is very key, suggest we clarifying that first. |
| Ericsson | Yes | If only one scheme should be selected for Rel-17, our view is delta-MCS should be supported, and “improved subband CQI granularity” should not be supported.  |

**Question 2-5**: Please indicate if FL proposal 8.2-1 is acceptable.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia | Yes  |  |
| HW/HiSi | [No] | It might be acceptable if the gNB has the possibility to trigger the delta-MCS report. Then, it can avoid situations where the increased payload of the PUCCH could cause harm, for example a decreased coverage or reliability of the feedback. Otherwise, we prefer to send the delta-MCS on a separate PUCCH.We think for the sake of progress, it would be beneficial to discuss the delta-MCS triggering, the resources and the target BLER together. |
| Intel |  | If RAN1 could not conclude on support/not support of delta-MCS, we are fine to limit the scope of the discussion to HARQ-ACK based reporting |
| Sony |  | We think this would benefit from a bit more discussion. There are benefits from sending it on the PUCCH carrying HARQ-ACK and on a separate PUCCH/PUSCH channel. As some companies suggested, multiple TBs’ delta-MCS can be combined, e.g. taking the average, and sent on a separate PUCCH/PUSCH channel which may reduce overhead. |
| Futurewei | No | We suggest making decision on whether delta-MCS scheme should be supported first before agreeing on the design details of the scheme.  |
| Samsung | Yes | Using a separate channel and defining delta\_MCS as another UCI type would have at least the following problems:1. Require new collisions resolution procedures for the UE/gNB.
2. Require new multiplexing procedures in PUSCH/PUCCH, on top of what is being discussed in intra-UE multiplexing.
3. For TDD systems, it would never exist in practice unless the gNB accepts scheduling restrictions or unless coverage is reduced by having PUCCH resources for HARQ-ACK and PUCCH resources for delta\_MCS in different symbols of a slot.
4. Would require substantial specification support.

None of the above is either necessary or acceptable to support delta\_MCS. Also, an “average” delta\_MCS would not provide any gains, if at all meaningful for a gNB to interpret and use for scheduling decisions.  |
| Apple | Yes |  |
| Ericsson | Yes |  |

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia | Partly | When gNB scheduling TBs, gNB use different BLER targets for different TBs and it is not fully feasible to assume that only two BLER targets will be used by the gNB towards the UE.If the UE assumes a fixed BLER target which is different from the target that gNB schedule the TB, report of delta-MCS may not be useful. We are not sure this was checked in the simulation studies. However, indicating used BLER target may not be fully reasonable as well. We also think this is related to which PDSCHs that the UE suppose to feedback the delta-MCS as reporting delta-MCS to all PDSCHs may be not useful due to extra overhead. So, prior agreeing to this, it is better we discuss 8.2.-3 or discuss everything in a single proposal.  |
| HW/HiSi | No | Making a decision now on which target BLER the UE shall assume can result into an inferior design in the later stages of this discussion. For example the UL overhead could become high or the gNB scheduling flexibility would be restricted. Before discussing this proposal, we should therefore decide whether the UE should be made aware of the target BLER that the gNB is using when scheduling the TB. |
| Intel | No | Although we are not supportive of the overall delta-MCS reporting mechanism, we need to point out that an MCS table was never associated with a target BLER to allow eNB/gNB scheduling flexibility. Thus, it is unclear how to select a value and how it can be used when reported. |
| Sony | Maybe | We can start with 2 BLER targets as working assumption. We think we do not need to tie it to an MCS table as this is rather limiting. The gNB can ask for a delta-MCS with target BLER = 10-5 for an eMBB PDSCH and we do not see why we need to stop the gNB from doing this.Our suggestion is:**Support at least two target BLER applicable to Delta-MCS calculation**  |
| Futurewei | No | We suggest making decision on whether delta-MCS scheme should be supported first before agreeing on the design details of the scheme.  |
| Samsung | Yes | A gNB can target different BLERs for transmissions of different TBs. Whether another BLER is configured by RRC would not make a difference. The only thing that matters is what MCS range the delta\_MCS can cover. As the entries in the MCS table are separated by about 0.9 dB and as it is not meaningful to have granularity of 1 MCS entry in the delta\_MCS reporting, having a granularity of 2-3 MCS entries can capture a large SINR range to cover any actual BLER using 2 bits for delta\_MCS. Alternatively, the DCI can indicate the BLER of the TB but that would require ~2 additional bits in the DCI and cannot be supported by DCI 1\_0 or for SPS PDSCH. For the above reasons, we support proposal 8.2-2.  |
| Apple | No | **Our preference is to have a single BLER target, also we**  don’t see the point to have “**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.”**
 |
| Ericsson | Maybe | For the first bullet, we are fine with at least supporting BLER=1e-1 and 1e-5.For the second bullet, it is premature to decide that the target BLER depends on the MCS table used to schedule the TB. It is more reasonable that gNB configures the target BLER that the UE should report delta-MCS for. For example, in current spec, gNB can schedule PDSCH using MCS table of one BLER target (1e-1), and request CQI for another BLER target (e.g., 1e-5) |

**Question 2-7**: Please indicate if FL proposal 8.2-3 is acceptable.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Nokia | Partly | Not sure what is covered by “per TB”.We do not think 1-bit report for all TBs are needed as that will add unnecessary overhead to the reporting of HARQ. Also as gNB uses different BLER targets, gNB may not get any useful feedback at the end. As the report is only needed for OLLA and may be for retarnmission (less useful), we do not have to consider all TBs when deriving feedback information. Having said that, we agree that, if delta-MCS is reported for a given TB, it can be a single bit.  |
| HW/HiSi | [No] | Could it be clarified: is the intention with “at least 1-bit per TB” that the delta-MCS report is always on, i.e. a delta-MCS must be reported for each TB? If this is the case, then we are not supportive, similar to Nokia, we also think that there are situations when a delta-MCS is not needed, or even could degrade the performance. It should be up to the gNB when to request a delta-MCS report. |
| Intel |  | Although we are not supportive of the overall delta-MCS reporting mechanism, we agree to evaluate further assuming at most 1-bit added to HARQ-ACK |
| Sony |  | We think that not all TBs require a delta-MCS report. If we support combining (e.g. average) multiple TBs’ delta-MCS into one report, then we may want more bits for that report. |
| Futurewei | No | We suggest making decision on whether delta-MCS scheme should be supported first before agreeing on the design details of the scheme.  |
| Samsung |  | The proposal does not seem necessary. The “at least one bit per TB” is practically a given (for TBs with delta\_MCS). The number of bits should be configurable to whatever the gNB wants them to be (within reason – e.g. 1, 2, 3) – there is no justification for hard-coding. We also support to discuss not having delta\_MCS reported for every TB and to have delta\_MCS be the HARQ-ACK because the ACK/NACK value and the delta\_MCS value are directly linked.  |
| Apple |  | We don’t need to dicuss this proposal until bigger issues are handled. |
| Ericsson | Maybe | We support the intention of FL proposal 8.2-3. To address the concern that delta-MCS may not be reported per TB, the proposal can be modified by adding “if reported for the given TB”. |

# 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%3A/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%3A/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
 |