**3GPP TSG RAN WG1 #105-e R1-2105975**

**e-Meeting, May 10th – 27th, 2021**

**Agenda Item: 8.3.1.2**

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

**Title: Feature lead summary #1 on CSI feedback enhancements for enhanced URLLC/IIoT**

**Document for: Discussion and Decision**

# Introduction

This contribution is a summary of contributions [2]-[22] 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, RAN1 agreed to study/evaluate a set of CSI enhancement schemes in terms of technical benefits, specification and implementation impacts. The candidate enhancement schemes include at least 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). RAN1 also agreed on a set of baseline assumptions for system-level simulations.

In RAN1#103-bis-e, RAN1 agreed to continue evaluation for a set of identified candidate schemes for Case 1 to address the fast interference change over time. RAN1 also agreed to continue studying and focus on Case 2 new reporting based on PDSCH decoding for OLLA performance enhancement for initial and re-transmissions of PDSCH.

In RAN1#104-e, a detailed set of Case 1 and Case 2 schemes was identified for continued evaluation ([23], Appendix B) and additional discussions took place after RAN1#104-e to better understand each scheme and associated aspects such as implementation complexity, specification impact and testability [24].

In RAN1#104b-e, RAN1 agreed to focus study for Case 1 on reporting of new metric determined based on network configured channel and interference measurement interval, increasing granularity of subband CQI and updating only CQI in a report. For new reporting Case 2, RAN1 agreed to focus on reporting of delta-CQI/MCS.

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 #104b-e

To be captured once agreement is made during this meeting

# Proposals for 1st GTW

TBD

# Proposals for 1st check point

TBD

# Proposals for 2nd check point

TBD

# Proposals for 3rd check point

TD

# Topic #1: New triggering methods for A-CSI and/or SRS

In this section, we provide summary of contributions discussing candidate enhancement schemes for new triggering methods.

## Summary of issues for Topic #1

Several contributions discuss potential benefits and drawbacks of supporting triggering of a A-CSI report by DCI:

**Issue #1-1: Support A-CSI triggering on PUCCH by DL assignment**

* Yes: Huawei [4], ZTE [5], vivo [8], NTT DOCOMO [20]
  + The development of new feedback reporting schemes (especially case 2 schemes) is impacted by whether aperiodic CSI can be reported on PUCCH or not [4].
  + Better performance than A-CSI on PUSCH and P/SP-CSI on PUCCH due to more flexible feedback [5],
  + Trigger reporting based on traffic needs for sporadic traffic [20]
  + No latency increase for CSI reporting (e.g. due to waiting for UL grant for triggering) [4]
  + Less uplink overhead than A-CSI on PUSCH in DL-heavy scenarios, or SP-CSI/P-CSI with low periodicity [20]
  + Transmission of single PDCCH transmission instead of two PDCCH with A-CSI on PUSCH [4][5][8]:
    - Less interference and resource utilization than A-CSI on PUSCH
    - Avoid blocking/increased latency from exceeding blind decoding limit per span or lack of coreset capacity
    - Better spectral efficiency
    - Avoid reduction of reliability due to CCE channel estimation limit
    - Avoid reduction of reliability from having to successfully receive two PDCCHs
* Some concerns: Lenovo [22]
  + Need to decide whether PUCCH resource is same or different than HARQ-ACK [22]
* No: Mediatek [21], LG [17]
  + P/SP-CSI reporting more suitable for factory scenario with periodic traffic [21]
  + For factory scenario, coherence time is larger than latency requirement, therefore no need to update the CSI report for re-transmission [21]
  + P/SP-CSI reporting every 10 ms sufficient for AR/VR scenario with 22 ms coherence time [21]
  + No clear enhancement compared to A-CSI on PUSCH [21]
  + If CSI and HARQ-ACK are combined in same resource, need to delay HARQ-ACK compared to processing capability 2 and increased probability of error with larger payload [21]
  + e.g. complicated timeline [19]
  + wasting resource since no retransmission is needed ~99% of the time [21]
  + Resources for CSI in the UL may be limited by other URLLC transmissions [19]

Several contributions discussed potential benefits and drawbacks of supporting triggering of a CSI-RS/SRS and/or A-CSI report by NACK:

**Issue #1-2: Support CSI-RS/SRS/A-CSI report triggering by NACK**

* Yes: Huawei [4], ZTE [5], Qualcomm [10]
  + No extra demands on PDCCH blind decoding
  + Avoid reduction of reliability due to CCE channel estimation limit
  + Good performance in terms of percentage of satisfied UEs [5]
  + Avoids excessive overhead of low CSI-RS periodicity/CSI report [10]
  + Can be used with semi-persistently scheduled PDSCH [10]
* No: Mediatek [21]
  + May increase power consumption by requiring unnecessary A-CSI computation 99% of the time [21]

Some contributions [3][4][15] identify that supporting new reporting Case 2 may require introduction of aperiodic triggering from DL DCI if the report is not transmitted as an extension of the HARQ-ACK codebook.

Two contributions [5][21] discuss potential support of triggering a A-CSI report by group DCI. However, neither contributions support this option. The main reason is the inefficient use of group DCI resources since packet arrivals are not synchronous between UEs.

Two contributions [5][20] propose to support priority handling for A-CSI on PUCCH, if supported.

One company [10] proposed to support UE requesting CSI measurement to update CSI (when UE autonomously updates its Rx beam).

One company [20] proposes to support A-CSI on PUCCH multiplexed on PUSCH repetition type B.

**Observations on new triggering methods.**

Compared to RAN1#104b-e, there does not seem to be any change of view or any additional data. Several companies do not discuss the topic any more in their contribution submitted to RAN1#105. For this reason, it is suggested to focus on Topic #2 and Topic #3 in RAN1#105.

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

TBD

# Topic #2: New reporting (Case 1)

In this section, we provide summary of contributions discussing candidate enhancement schemes for new reporting based on channel/interference measurement (Case 1).

## Summary of issues for Topic #2

At RAN1#105, it was agreed to focus study of Case 1 new reporting to the following schemes:

* Reporting of new metric determined based on network configured channel and interference measurement interval. The new metric is to be downselected in RAN1#105-e.
  + The new metric is to enable the scheduler to pick a MCS based on the tail of distribution of possible channel quality experienced at the scheduling time.
* Increasing granularity of subband CQI (e.g. 3-bits differential subband CQI or 4-bits full subband CQI).
  + The increased granularity is to avoid inaccurate subband CQI report when a subband CQI is much worse than wideband CQI
* Updating only CQI in a report, where CQI is conditioned on a previous instance in which RI/PMI/(CRI) is updated.
  + The update of CQI only may enable reduction of delay between CQI measurement and reporting

In following sections, performance results and views on each scheme are presented.

## Reporting of new metric

### Statistical CSI/SINR (Case 1-1)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-1  Mean and stdev SINR  (K=5, L = 100) | AR/VR | 85% satisfied UEs [48%]  26% RU [71%] |
| Futurewei [2] | Case 1-1  Mean and stdev SINR  (K=10, L = 200) | AR/VR | 80% satisfied UEs [48%]  31% RU [71%] |
| ZTE [5] | Case 1-1  Mean + stdev CQI | AR/VR | 31% satisfied UEs [50%]  2.9% RU [1.9%]  (gNB sets MCS based on MeanCQI – StdevCQI) |
| InterDigital [18] | Case 1-1  Mean+stdev SINR | AR/VR  (20 UEs /cell) | 93% satisfied UEs [85%]  7.6 RU [6.5 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 1-1  Mean+stdev SINR | Factory  (20 UEs /cell) | 96% satisfied UEs [98%]  5.9 RU [1.3 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 1-1  Mean+stdev SINR | Factory  (40 UEs /cell) | 64% satisfied UEs [9%]  6.4 RU [3.4 RU]  Report periodicity 20 ms |
| Nokia [19] | Case 1-1  Mean + stdev SINR | Factory | 1 ms 99.9999%-pct latency [2 ms]  5% RU [3%] |
| Ericsson [26] | Case 1-1  Mean and stdev CQI (wideband) | AR/VR  (mixed traffic) | 97.5% satisfied UEs [78.5%]  76% median RU [77%]  Baseline uses fixed backoff of 20 dB |
| Ericsson [26] | Case 1-1  Mean and stdev CQI (subband) | AR/VR  (mixed traffic) | 97.2% satisfied UEs [78.5%]  60% median RU [77%]  Baseline uses fixed backoff of 20 dB |
| Intel [12] | Case 1-1  Mean+stdev SINR  (IMR for actual loading) | Factory | 42% satisfied UEs [42%]  6.3% RU [6.3%] |
| Intel [12] | Case 1-1  Mean+stdev SINR  (IMR for full loading) | Factory | 57% satisfied UEs [37%]  30.48% RU [24%] |

Company views

Supportive: Ericsson [3], CMCC [9], Intel [12], Sony [14], Nokia [19] (SINR only), (NTT DoCoMo [20]), Lenovo [22]

* Does not require LA backoff parameter optimization, shows superior performance [3]
* Other evaluations underestimated benefit due to not using mean-SINR, biasing reported mean-SINR, or assuming improper use of the mean/std-SINR reports in scheduling [3]
* Support larger sample of measurements [9]
* More reliable than instantaneous measurement [12]
* Multiple CSI reports do not work on the borders of SINR range of CQI [12]
* Compresses multiple measurements in single report (overhead reduction) [14][20]
* (for SINR) Allow channel characterization and link adaptation for any BLER and TBS (performance uncertainty from different UE implementations smaller than uncertainty from fading profile with CQI) [19]

Concerns: Futurewei [2], Huawei [4], ZTE [5], Spreadtrum [7], CATT [8], Apple [13], Quectel [15], Samsung [16], LG [17], Nokia [19] (CQI only)

* Including signal part in the statistics increases uncertainty with large sampling period if signal part is known from recent CSI report [2] (this assumes that mean SINR is not reported?)
* Prior knowledge of distribution is necessary at gNB side [4]. Unclear if mean and stdev are right quantities for feedback if distribution is unknown [13][16]
* Difficult to define/specify std-CQI/SINR table, high standards effort [4][5][7][16]
* Unclear how to perform testing [8]
* (for SINR): Performance for given SINR is implementation dependent [15][16][17]
* Increased UE complexity to perform filtering [4][15]
* Overhead increase if per-subband statistics need to be reported [16]
* Can provide frequent CQI reports instead [4][16][17]
* (for CQI): report quantity applies only to assumed TBS and target BLER, requires adjustments and may be inaccurate [19]

Aspects to further study:

* Control/configuration of measurement time range or number of measurements for mean/stdev CQI [9]
* Using mean, stdev, min or max [12]
* Whether to report reference CSI reporting to address testability issues [13]
* Time window size, minimum number of CSI samples, whether to exclude outliers, how to quantize and report statistics [22]

### Interference statistics (Case 1-3)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-3  stdev of interference  (K=5, L=100) | AR/VR | 90% satisfied UEs [48%]  24% RU [71%] |
| Futurewei [2] | Case 1-3  stdev of interference  (K=10, L=200) | AR/VR | 92% satisfied UEs [48%]  22% RU [71%] |

Supportive: Futurewei [2], Intel [12]

* No existing R16 solution available to provide gain [2] because of quantization issues with legacy CQI
* Low feedback overhead (e.g. every 100 TTIs) [2]
* Low implementation complexity since interference needs to be measured anyway [2]
* Low specification impact – only need to add new reporting quantity for interference stdev/variance [2]
* Testable with controllable interference source [2]
* Simple, mature concept [2]

Concerns: Ericsson [3], Huawei [4], ZTE [5], Spreadtrum [7], CATT [8], Sony [14], Quectel [15], Samsung [16], Nokia [19], NTT DoCoMo [20], Lenovo [22]

* Assumes certain type of receiver (MRC), does not take into account spatial properties of interference [3][15]. Was discussed and not adopted in eMIMO for this reason [3]
* Prior knowledge of distribution is necessary at gNB side [4][16]
* Required information may vary depending on gNB scheduling algorithm [20]
* Can provide frequent CQI reports instead [4]
* Not self-contained as interference stdev report cannot be used by itself [3], unclear how to combine with other CSI quantities [17]
* Difficult to define/specify [7], higher spec impact than statistical CQI/SINR [4][5][16]
* Unclear how to perform testing [8]
* Need mean value of interference, information is similar to mean+stdev CQI/SINR [14]
* Increased UE complexity to perform filtering [4][15]
* Network can use long-term RSRP and RSSI measurements instead [16]
* Large dynamic range of interference, may not capture deep fade of desired signal [17]
* Benefit over statistical CQI/SINR is not clear [22]

### CSI based on worst IMR occasion (Case 1-5)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-5  CSI based on worst IMR occasion | AR/VR | 70% satisfied UEs [48%]  38% RU [71%] |
| ZTE [5] | Case 1-5  CSI based on worst IMR occasion | AR/VR | 58% satisfied UEs [50%]  2.3% RU [1.9%] |
| Intel [12] | Case 1-5  CSI based on worst IMR occasion  (IMR for actual loading) | Factory | ??% satisfied UEs [42%]  6.3% RU [6.3%] |
| Intel [12] | Case 1-5  CSI based on worst IMR occasion  (IMR for full loading) | Factory | 61% satisfied UEs [37%]  46% RU [24%] |
| InterDigital [18] | Case 1-5  CSI based on worst IMR occasion | AR/VR  (20 UEs /cell) | 84% satisfied UEs [85%]  7.1 RU [6.5 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 1-5  CSI based on worst IMR occasion | Factory  (20 UEs /cell) | 83% satisfied UEs [98%]  2.3 RU [1.3 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 1-5  CSI based on worst IMR occasion | Factory  (40 UEs /cell) | 14% satisfied UEs [9%]  4.7 RU [3.4 RU]  Report periodicity 20 ms |

Supportive: Huawei [4], ZTE [5], Spreadtrum [7], (LG [17]), (InterDigital [18]), Lenovo [22]

* Easy to implement [4], [5]
* Can reflect interference variations in time [5], avoid having to use too low MCS [5]
* Avoids continuous CSI reporting [17]

Concerns: Futurewei [2], CATT [8], CMCC [9], Sony [14], Quectel [15], Samsung [16]

* Worst IMR in a recent occasion may not represent worst-case IMR that can happen [2][3][9]
* Unclear benefit compared to subband reporting [8]
* Provides less information than statistical CSI [14]
* Increased UE complexity to perform filtering [15]
* Network can apply a backoff without this measurement [16]
* WB information insufficient, unclear definition of worst occasion for sub-band CQI [17]

Aspects to consider further:

* Definition of worst IMR [4]
* Definition/selection of IMR occasion with multiple configured CSI-RS [4]

### Worst-M CQI (Case 1-6/1-7)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-6  Worst-M CQI | AR/VR | 76% satisfied UEs [48%]  31% RU [71%] |
| Nokia [19] | Case 1-6  Worst-2 CQI | Factory | ~1 ms 99.999%-pct latency [2 ms]  5% RU [3%] |
| Nokia [28] | Case 1-6  Worst-M CQI  Single IMR | AR/VR  (Mixed traffic) | 77% satisfied UEs [74%, single IMR]  Report periodicity 2 ms |
| Nokia [28] | Case 1-6  Worst-M CQI  Single IMR | AR/VR  (Mixed traffic) | 73% satisfied UEs [74%, single IMR]  Report periodicity 10 ms |
| Nokia [28] | Case 1-6  Worst-M CQI  Multiple IMR | AR/VR  (Mixed traffic) | 100% satisfied UEs [74%, single IMR]  Note: R16 subband CQI + multiple IMR has 100% satisfied UEs  Report periodicity 10 ms |
| InterDigital [18] | Case 1-6  Worst-M CQI | AR/VR  (20 UEs /cell) | 93% satisfied UEs [88%]  6.8 RU [6.5 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-6  Worst-M CQI | Factory  (20 UEs /cell) | 100% satisfied UEs [98%]  2.0 RU [1.3 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-6  Worst-M CQI | Factory  (40 UEs /cell) | 68% satisfied UEs [9%]  4.8 RU [3.4 RU]  Report periodicity 2 ms |

Supportive/open: Huawei [4], Qualcomm [10], Quectel [15], LG [17], InterDigital [18], Nokia [19], NTT DoCoMo [20], Lenovo [22]

* Simple extension of R16, low implementation impact [4][15][19][20]
* Reduce overhead and ensure high downlink reliability [10]
* More aligned with current CSI framework compared to other schemes [17]
* Avoids continuous CSI reporting [17]
* Testable [19]
* Can include CSI based on worst IMR occasion if worst IMR occasion is selected for reporting

Concerns: Futurewei [2], Ericsson [3], ZTE [5], Spreadtrum [7], CATT [8], Apple [13], Samsung [16]

* Worst CQI in a recent measurement may not represent worst-case CQI that can happen [2][3]
* Benefit only in Factory scenario for which interference in time is predictable. Does not benefit for AR/VR [3]
* Only provides worst-CQI in frequency [7]
* Only benefit compared to subband reporting is overhead [5][8][16]
* Unclear if stationarity for interference can be assumed. If network coordination makes interference more predictable, reporting can be achieved by reportFreqConfiguration [13]

Aspects to study further:

* Handling of multiple CSI-RS resources [10]
* Whether to report one or subset of worst CQIs [10]
* 4-bits or D-CQI for the worst-case, adding to or replacing existing CQI [19]

## Increasing granularity of subband CQI (Case 1-8)

|  |  |  |  |
| --- | --- | --- | --- |
| Intel [12] | Case 1-8  4-bits full CQI | Factory  IMR for actual loading | 43%(?) satisfied UEs [42%]  6.3% RU [6.3%] |
| Intel [12] | Case 1-8  4-bits full CQI | Factory  IMR for full loading | 32% satisfied UEs [37%]  24% RU [24%] |
| Samsung [16] | Case 1-8  3-bit Diff-CQI | ??? | 0.2%, 1.9%, 1.0% gain for average/median/5 pctile throughput respectively. |
| Samsung [16] | Case 1-8  4-bits full CQI | ??? | 0.5%, 0.7%, 15.6% gain for average/median/5 pctile throughput respectively |
| InterDigital [18] | Case 1-8  3-bits Diff-CQI | AR/VR  (20 UEs /cell) | 88% satisfied UEs [88%]  6.5 RU [6.5 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-8  3-bits Diff-CQI | Factory  (20 UEs /cell) | 95% satisfied UEs [98%]  1.3RU [1.3 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-8  3-bits Diff-CQI | Factory  (40 UEs /cell) | 7.8% satisfied UEs [8.8%]  3.3 RU [3.4 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-8  4-bits full CQI | AR/VR  (20 UEs /cell) | 88% satisfied UEs [88%]  6.5 RU [6.5 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-8  4-bits full CQI | Factory  (20 UEs /cell) | 95% satisfied UEs [98%]  1.3 RU [1.3 RU]  Report periodicity 2 ms |
| InterDigital [18] | Case 1-8  4-bits full CQI | Factory  (40 UEs /cell) | 8% satisfied UEs [9%]  3.3 RU [3.4 RU]  Report periodicity 2 ms |
| Nokia [20] | Case 1-8  4-bits full CQI | Factory | 1 ms 99.9999%-pct latency [2 ms]  6% RU [3%] |
| Mediatek [21] | Case 1-8  3-bits Diff-CQI | Factory | 0.4% of incorrect MCS [22%]  Baseline uses 2-bit D-CQI  Incorrect MCS defined as scheduled MCS using scheme minus scheduled MCS using 4-bits SB-CQI |
| Mediatek [21] | Case 1-8  3-bits Diff-CQI | Factory | 21.2% RU (25.1%) |
| Mediatek [21] | Case 1-8  4-bits full CQI | Factory | 21.2% RU (25.1%) |

Supportive: Huawei [4], Spreadtrum [7], Sony [14], Samsung [16], NTT DoCoMo [20], Mediatek [21]

* Increases accuracy of the subband report [4][14][20][21]
* Little specification effort [7][20]

Concerns: Ericsson [3], Intel [12], Apple [13], InterDigital [18], Nokia [19]

* Does not help if interference is unpredictable in time [3]
* Increases overhead [19] by up to 43% (3 bits) or 87% (4 bits) [3]
* Gains are not sufficient [12][18]
* Cannot assume stationarity of interference [13]

## Updating CQI-only (Case 1-11)

|  |  |  |  |
| --- | --- | --- | --- |
| Huawei [4] | 0.5 ms delay between CSI meas. and report  (for all reports) | Factory  12 UEs per cell | 100% satisfied UEs [70%] |
| Huawei [4] | 0.5 ms delay between CSI meas. and report  (for all reports) | Factory  15 UEs per cell | 69% satisfied UEs [37%] |
| Huawei [4] | 1 ms delay between CSI meas. and report  (for all reports) | Factory  (non-baseline) | 100 supported UEs for 100% availability [70] |
| Vivo [6] | Case 1-11  Full CSI every 20 ms  Update CQI based on CSI-RS and IMR every 5 ms | AR/VR | 89% satis. UEs [83%, baseline1]/[87%, baseline2]  57% RU [62%, baseline1]/[57%, baseline2]  Baseline 1 uses full CSI recalculation every 20 ms  Baseline 2 uses full CSI recalculation every 5 ms |
| InterDigital [18] | Case 1-11  Full CSI every 20 ms  Update CQI based on IMR every 2 ms | AR/VR  (20 UEs /cell) | 85% satis. UEs [85%, baseline1]/[88%, baseline 2]  6.9 RU [6.9 RU, baseline1]/[6.5 RU, baseline2]  Baseline 1 uses full CSI recalculation every 20 ms  Baseline 2 uses full CSI recalculation every 2 ms |
| InterDigital [18] | Case 1-11  Full CSI every 20 ms  Update CQI based on IMR every 2 ms | Factory  (20 UEs /cell) | 97% satis. UEs [98%, baseline1]/[98%, baseline 2]  1.3 RU [1.3 RU, baseline1]/[1.3 RU, baseline2]  Baseline 1 uses full CSI recalculation every 20 ms  Baseline 2 uses full CSI recalculation every 2 ms |
| InterDigital [18] | Case 1-11  Full CSI every 20 ms  Update CQI based on IMR every 2 ms | Factory  (40 UEs /cell) | 9.6% satis. UEs [8.5%, baseline1]/[8.8%, baseline 2]  3.4 RU [3.3 RU, baseline1]/[3.4 RU, baseline2]  Baseline 1 uses full CSI recalculation every 20 ms  Baseline 2 uses full CSI recalculation every 2 ms |
| Nokia [28] | Case 1-11  Full CSI every 10 ms  Update CQI every 2 ms | AR/VR | 93% satis. UEs [92%, baseline1]/[93%, baseline2]  Baseline 1 uses full CSI recalculation every 10 ms  Baseline 2 uses full CSI recalculation every 2 ms |
| Nokia [28] | Case 1-11  Full CSI every 20 ms  Update CQI every 2 ms | AR/VR | 93% satis. UEs [91%, baseline1]/[93%, baseline2]  Baseline 1 uses full CSI recalculation every 20 ms  Baseline 2 uses full CSI recalculation every 2 ms |

Supportive: Huawei [4], Vivo [6], Spreadtrum [7], Oppo [11], NTT DoCoMo [20]

* Requires less computation time and can reduce gap between measurement and scheduling instance [4][5][20]
* Legacy processing delay for subband CQI is too long for URLLC – need delay requirement 1 [4][6]
* Reducing CSI computation improves performance [4][6][7]
* Overhead reduction in UCI (if RI/PMI not reported) [7]
* Spatial related information may not change frequently [11]
* Computation complexity reduced from O(192) to O(1) [11]
* Low implementation and spec impact [20]

Concerns: Ericsson [3], CATT [8], Intel [12], Sony [14], Samsung [16], Nokia [19], Mediatek [21]

* Splitting report across multiple instances risks mis-detection and error propagation [3][16]
* Splitting report across multiple instances violates self-contained principle adopted in NR from R15 and would increase specification complexity (introduce new mode, specify CPU occupancy and CSI timeline) [3]
* Can be achieved by implementation in R16 by utilizing two CSI report configurations and different reporting frequencies [3]
* Can be achieved by implementation in R16 by restricting rank to 1 and obtaining PMI from SRS [16]
* Out-performed by statistical CSI/SINR since it cannot use CSI-IM time occasions occurring before and after a CSI-RS time occasion [3].
* No benefit if CSI processing time cannot be reduced compared to R16 [8][14]
* Does not directly solve problem of more accurate MCS selection [12]
* Possible CSI processing time reduction is limited to 10%-20% [16]
* Performance impact if CRI/PMI/RI actually changes [19]. May need to define conditional CRI/PMI/RI omission rules.
* Degrades performance compared to full CSI updates [21]

Aspects to study further:

* How many symbols can be reduced for CSI processing time [5] and what would the performance gain be
* Definition of “previous instance in which RI/PMI/(CRI) is updated”, same CSI-ReportConfig or linked CSI-ReportConfig [11]
* Potential payload size ambiguity [17]
* How to trigger CQI only update [17]

## Observations for Topic #2

For reporting of new metric to enable more accurate selection, four schemes were studied and analyzed by companies:

**Statistical CQI/SINR** (mean + stdev CQI/SINR): This scheme was evaluated by multiple companies and a significant gain is observed by most. The main benefit of this scheme is that it may provide the network with a good picture of the main characteristics of the CQI distribution (mean and standard deviation), from which the CQI at the tail of the distribution can be estimated. The main concern is the higher complexity (relative to other schemes) for the UE to obtain the quantities.

**Interference statistics** (stdev of interference): This scheme was evaluated by one company who observes even higher gain compared to statistical CQI/SINR. The main benefits and concerns are similar to statistical CQI/SINR. However, there is a significant additional concern related to the “explicit feedback” nature of the report which makes practical usability difficult considering varying UE receiver implementations. Based on company inputs, it seems unlikely that consensus on supporting this scheme is achievable in R17.

**CSI report based on worst IMR**: This scheme was evaluated by several companies and in most cases a gain can be observed. The main benefit of this scheme is that it is generally considered low complexity, although additional discussion would be needed for the definition of “worst-IMR” in case of sub-band CQI. A concern is that reporting of a “worst” CQI experienced in the recent past may not be representative of the worst CQI at a very low probability level.

**Worst-M CQI**: This scheme was evaluated by several companies and a gain is observed in most cases. The main benefit of this scheme is that it is low complexity, although additional discussion would be needed for the definition in case of multiple measurement resources in time domain. Similar to the previous scheme, a concern is that reporting of a “worst” CQI experienced in frequency domain may not be representative of the worst CQI at a very low probability level particularly when traffic is not periodic.

From the above, the schemes that have most support appear to be Statistical CSI/SINR (7 companies) and Worst-M CQI (8 companies). Between the two schemes, moderator suggestion is to take consideration of the complexity and time remaining in the work item. From this perspective, the worst-M CQI scheme appears preferable since a lot of potentially difficult discussions can be avoided (e.g. whether to use CQI or SINR, details of stdev estimation, quantization, etc.). The worst-M CQI scheme also appears to not present difficulty from perspective of testing. By configuring frequent reporting of worst-M CQI in time domain, it may also be possible for a network implementation to infer CQI at very low probability and achieve the same objective as with reporting of standard deviation of CQI.

Although the definition of worst-M CQI is straightforward when considering a single measurement instance in time domain, the case of multiple measurement instances could be further investigated (e.g. whether to take average in time domain first, to take minimum in both frequency and time domains, etc.).

**FL proposal 8.1-1**: **Support new metric based on network configured channel and interference measurement interval, where new metric is a minimum CQI value at least in frequency domain (“worst-M CQI”).**

* **FFS: Definition with multiple channel and interference measurement instances within time interval**

For **increasing granularity of subband CQI**, this scheme could be utilized by the scheduler in the same way as worst-M CQI, or statistical CSI/SINR, by utilizing the reports to derive a low-probability CQI and achieve similar performance. However, several companies have concern that the overhead increase to achieve this would be prohibitive as reports need to be very frequent, and the increased payload by report would be 43% (for 3-bits D-CQI) or 87% (for 4-bits CQI) compared to legacy subband D-CQI. Another way that the scheme could provide benefit is by improving accuracy in case the scheduler selects subband based on the last reported CQI report, even though the results so far do not show consistent gains in URLLC scenarios at least with the CSI computation latency of R16.

Considering the concerns related to increased overhead, moderator suggestion is to agree that if new type of subband CQI with increased granularity is supported, the maximum number of bits per subband CQI value is 3.

**FL proposal 8.1-2: If increasing granularity of subband CQI is supported, the maximum number of bits per subband CQI is 3 bits.**

For **updating of CQI-only**, evaluation results with CSI processing time unchanged from R16 do not consistently show improvement from baseline with lower periodicity. One company observed improvement when reducing CSI processing latency to 0.5 ms. In view of these evaluation results, moderator suggestion is to only consider this scheme along with a reduction of CSI processing latency for the reports where only CQI is updated.

Some companies have concerns with deviating with the principle of transmitting self-contained CSI reports as it would introduce additional complexity to deal with missing CSI reports and error propagation. It was also pointed out that a type of CQI-only reporting very close to the proposed scheme could be achieved by configuration in R16. Considering these concerns, moderator suggestion is to agree that self-contained CSI reports would continue to be used if this scheme is supported.

**FL proposal 8.1-3**: **If reporting with CQI-only update is supported:**

* **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
  + **Note: this does not preclude use of new report based on configured channel and interference measurement, if supported.**
* **Support shorter CSI computation time compared to R16.**

## 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 (such as evaluation results or company position) or (b) add your company position relative to the schemes listed in the above.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi |  | Given the diversified views from companies, we think it is difficult for the progress to have 3 separate proposals in Case 1 (one for each bullet from last meeting, i.e. statistic schemes, sub-band accuracy and for partial CQI update).  Instead, we think progress could be better if we would have one common proposal that includes multiple schemes and we should make this decision early.  Maybe this was not so clear from our paper, we are in general sceptical about the technical benefits of the schemes that were listed under the first bullet from last meeting’s agreement (i.e. the statiscal schemes) but we could accept one of them, if also other methods that in our view are more technical meaningful could be supported. Which of the candidate schemes under the first bullet to select, we don’t have a very strong view. |
| Nokia |  | One comment on,  **“Statistical CQI/SINR** (mean + stdev CQI/SINR): This scheme was evaluated by multiple companies and a significant gain is observed by most. The main benefit of this scheme is that it may provide the network with a good picture of the main characteristics of the CQI distribution (mean and standard deviation), from which the CQI at the tail of the distribution can be estimated. The main concern is the higher complexity (relative to other schemes) for the UE to obtain the quantities. “  This is mainly capturing CQI distribution aspects only. But, knowing CQI distribution does not help compared to SINR distribution. It would be good to capture the difference of this two schemes. |
| Ericsson |  | Please update Ericsson view of the following:   * 8.2.3 CSI based on worst IMR occasion (Case 1-5): Please add Ericsson to the list of companies that do not support this scheme;   Also, we disagree with moderator statement for “Worst-M CQI”: “By configuring frequent reporting of worst-M CQI in time domain, it may also be possible for a network implementation to infer CQI at very low probability and achieve the same objective as with reporting of standard deviation of CQI.” If frequent reporting, then existing CQI reporting (wideband, subband) can also provide probability information. The benefit of statistical CQI reporting is, the probabilisitic information can be provided to gNB without frequent reporting. Thus, it is incorrect to say that worst-M CQI can achieve the same objective as statistical CQI. |
|  |  |  |

**Question 2-2**: Please indicate if FL proposal 8.1-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | No | Information using worst M sub-band CQI can already be achieved with the existing sub-band CQI report. Unclear why we need to mechanisms to provide the same information. |
| HW/HiSi | No | This proposal goes directly to support one scheme. At this stage, we think more discussion is needed and this proposal should be handled equivalently to the other proposals, i.e. start with “if supported,…”.  Then, as indicated in our answer to Question 2-1, even if we are still sceptical about the technical benefits of the candidate schemes behind this proposal, for the matter of progress, we would like to work constructively on a compromise solution. We would think it could be great if we as a group could specify multiple schemes, e.g. partial CQI update and a statistical scheme. Which one to select from the statistic candidates, we don’t have a strong view. |
| Nokia | Yes | Wording could be improved, **“ minimum CQI value at least in frequency domain”** may be misunderstood by the companies. Other than that no big issue as this seems to be the most technically right decision that RAN1 can take on enhancing CSI feedback. |
| Samsung | No | The gNB can obtain all information based on Rel-15 configurations. It is not even clear if the proposal can achieve even marginal overhead reduction for few 2-bit SB differential CQIs as it needs to indicate reported subbands. |
| Ericsson | No | Do not support Worst-M CQI.  This method does not provide performance improvement for realistic sceanario where the interference is unpredictable in both time and frequency. |
| Futurewei | No | Our performance evaluation results show that performance of Worst-M CQI is worse than both Case 1-3 (Interference statistics) and Case 1-1, with Case 1-3 having the best performance. Comparison of performance of different schemes should be the most important criteria to decide scheme(s) to be supported and that is why companies were encouraged to conduct performance evaluation of different schemes. Based on the performance comparison, we cannot support this proposal. |

**Question 2-3**: Please indicate if FL proposal 8.1-2 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | We think both a 3-bits differential CQI or full 4-bit for CQI should be included, this gives more flexibility. Which one to use could be configured by the network. It is straight forward and does not require a large specification effort.  We disagree with that the overhead always is larger for the 4-bit absolute CQI. It depends on how many sub-bands are configured. For three sub-bands, for example, 3 extra bits are needed for the sub-band report, but then the 4-bit wideband CQI does not need to be reported. In that case the 4-bit sub-band CQI would have 1 bit less overhead. In general, the overhead difference between these two schemes is not significant, and if a certain use case would rather need low UL overhead than reporting accuracy, then the gNB always has the possibility to stick to the legacy report with 2 bits.  Additionally, it is our view that an improved reporting accuracy also requires improved accuracy of the measurements. The measurement accuracy of the CQI can be improved with scheme 1-11 (if a faster CQI calculation time is supported). In our view 1-8 and 1-11 with faster CQI processing time should be supported together. |
| Nokia | No | This was discussed a lot in the past and never adopted due to the significant overhead. We do not think that this is practically useful. Frequent reporting has to configure to know interference variation, and a very large overhead is not helping. From our view, this enhancement is more for eMBB than URLLC. |
| Samsung | Yes/Neutral | It can be acceptable because it is trivial to support, up to the gNB to configure the number of bits, and we observe some small gains at the 5% geometry CDF. |
| Ericsson | No | Do not support increasing granularity of subband CQI (Case 1-8).  With 3-bit granularity, this method still increases CSI overhead significantly (>=39% for 100 PRB BWP [3]).  On the other hand, performance benefit from this method does not justify the overhead. It improves performance only when interference is predictable w.r.t time but not frequency. There is little performance gain when interference is un-predictable w.r.t both time and frequency, which is typical in real life operation. |
| Futurewei | Neutral | We are open to discuss if both 3-bit and 4-bit subband CQI can be considered and whether 3-bit or 4-bit is used can be configured by gNB. |

**Question 2-4**: Please indicate if FL proposal 8.1-3 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | No | No point leaving this still open given that it did not have overwhelming support. |
| HW/HiSi | [Mostly Yes] | We are supportive in principle to this scheme but would like to keep some detail for FFS for now.  We are fine with the sub-bullet to support a shorter CSI computation time. This is the most important part of this scheme and it would ne good to decide it now.  For the self-contained reports, we would like to keep it FFS at this stage. According to our understanding, also in Rel-16 CQI can for example be reported without PMI. There is configuration where only CRI/RI/CQI is reported. Also, maybe other methods like a pre-configured rank and an assumption on the precoding matrix could be used. |
| Nokia | No | We showed the performance loss with this approach and do not think solving the concerns on accurate MCS selection even with faster feedback |
| Samsung | Neutral/No | Overhead benefits are not applicable because “CQI-only” can be achieved based on Rel-15 configurations (e.g. with rank restriction for a given configuration).  Timeline reduction may exist for the “best-case” wideband CQI reporting but it will be marginal (e.g. 1 symbol at 15 kHz SCS) and there will be some spec/UE impact associated with its support. |
| Ericsson | No | Do not support reporting CQI-only update (Case 1-11).  As discussed in our contribution [3], this method has numerous issues such as violating the self-contained principle in NR CSI design.  Regarding “shorter CSI computation time”: this is only applicable for the instances where CQI-only is updated, and it is not applicable in the instances when RI/PMI are reported. |
| Futurewei | Neutral | We are open to have further discussion on this and potential combination of Case 1-11 with other Case 1 scheme(s). |

# Topic #3: New reporting (Case 2)

## Summary of issues for Topic #3

At RAN1#105, it was agreed to focus study of Case 2 new reporting to delta-MCS/CQI. Several companies provided evaluation results for this scheme.

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| ZTE [5] | Case 2-3  (Delta SINR)  Initial transmission | AR/VR | 61% satisfied UEs [50%]  2.3% RU [1.9%] |
| ZTE [5] | Case 2-3  Retransmission: Delta SINR (3-bit) | AR/VR | 94% satisfied UEs [50%]  33% RU [1.9%] |
| ZTE [5] | Case 2-3  Retransmission: Delta MCS (3-bit) | AR/VR | 60% satisfied UEs [50%]  1.9% RU [1.9%] |
| Intel [12] | Case 2-3  (Delta SINR)  Initial transmission  (IMR for actual loading) | Factory | 42% satisfied UEs [42%]  6.4% RU [6.3%] |
| Intel [12] | Case 2-3  (Delta SINR)  Initial transmission  (IMR for full loading) | Factory | 35% satisfied UEs [37%]  27% RU [24%] |
| Qualcomm [16] | Case 2-3  Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 20 URLLC UEs) | 100% satisfied UEs [100%]  3471 RBs for 2nd Tx [5255] |
| Qualcomm [16] | Case 2-3  Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 100 URLLC UEs) | 100% satisfied UEs [100%]  5878 RBs for 2nd Tx [7545] |
| InterDigital [18] | Case 2-3  Initial transmission: Report delta-MCS (1 bit) | AR/VR  (20 UEs /cell) | 99% satisfied UEs [99%]  7.0 RU [7.0 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Initial transmission: Report delta-MCS (1 bit) | Factory  (20 UEs /cell) | 100% satisfied UEs [100%]  3.2 RU [3.4 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Initial transmission: Report delta-MCS (1 bit) | Factory  (40 UEs /cell) | 97% satisfied UEs [99%]  4.3 RU [3.4 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (1 bit) | AR/VR  (20 UEs /cell) | 97% satisfied UEs [99%]  7.0 RU [7.0 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (1 bit) | Factory  (20 UEs /cell) | 100% satisfied UEs [100%]  3.5 RU [3.4 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (1 bit) | Factory  (40 UEs /cell) | 100% satisfied UEs [99%]  4.9 RU [3.4 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (5 bits) | AR/VR  (20 UEs /cell) | 93% satisfied UEs [99%]  7.0 RU [7.0 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (5 bits) | Factory  (20 UEs /cell) | 100% satisfied UEs [100%]  3.4 RU [3.4 RU]  Report periodicity 20 ms |
| InterDigital [18] | Case 2-3  Retransmission: Report delta-MCS (5 bits) | Factory  (40 UEs /cell) | 100% satisfied UEs [99%]  4.7 RU [3.4 RU]  Report periodicity 20 ms |

The agreement from RAN1#104b-e states that delta-MCS/CQI is to be studied but there is no agreement to support yet. Based on the submitted input, the support from companies can be summarized as follows (some companies that did not express clear preference are not listed).

**Issue #3-1**: Support Delta-CQI/MCS reporting?

Supportive: Ericsson [3], Spreadtrum [7], CATT [8], Qualcomm [10], OPPO [11], (Sony [14]), Samsung [16], InterDigital [18], Nokia [19]

Concerns: Futurewei [2], Huawei [4], Intel [12]

* Need to better understand how it helps gNB improve MCS selection before deciding [2]
* Need to agree on supporting A-CSI on PUCCH first [4]
* Uncertain performance benefits at expense of high spec impact [12]

The agreement from RAN1#104b-e states that delta-MCS or delta-CQI can be studied. A number of companies provided analysis on which of the two options is preferable, and further on how to determine the reference MCS or CQI for the “delta” signaling.

**Issue #3-2**: Whether to report delta-MCS or delta-CQI?

* Delta-MCS: Ericsson [3], CATT [8], Qualcomm [10], OPPO [11], Sony [14], Quectel [15], Samsung [16], InterDigital [18]
  + Reporting is based on actual transmission with specific MCS [3]
  + MCS granularity is finer than CQI [3][8]
  + No additional overhead of measurement resource or computation time budget [11]
  + Less computation at the UE (CQI would require conversion) [14][16]
  + Delta-CQI would depend on scheduler implementation [15]
  + Definition: BLER with index Imcs+Dmcs is smaller than/equal to BLER of MCS table for TB [16].
* Delta-CQI: Huawei [4]
  + Minimize specification impact [4]

**Issue #3-3:** Reference CQI/MCS

* Scheduled MCS: CATT [8], Qualcomm [10], OPPO [11], Samsung [16], InterDigital [18]
  + No error propagation issue that would occur if it would be referred to previous report [11]
* Do not use MCS of PDSCH as reference for delta-CQI/MCS report: Huawei [4]
  + Due to mismatch between BLER as previous CQI report and target BLER of the PDSCH (if BLER of previous CQI report is used as target BLER for reporting)

A few companies discuss how the UE determines the target BLER for the determination of delta-MCS/CQI:

**Issue #3-4:** Target BLER

* Semi-static configuration: Ericsson [3], Sony [14] (per SPS config)
  + Using values from configured CQI tables (1e-1 or 1e-5) not flexible enough for gNB [3]
* Dynamically from RNTI of the DL assignment: Sony [14]
* Same BLER as previous CQI report: Huawei [4] (“option 1”)
* Tied to the MCS table used for PDSCH: Samsung [16]

The following issues (3-5/3-6/3-7) relate to triggering and reporting aspects. A first question (3-5) is on whether the new report should be transmitted as part of the HARQ-ACK codebook or in a separate resource. In case the new report would be transmitted in a separate resource, the issue of how to trigger (and provide resource) needs to be considered (3-6). In addition, many companies discussed the issue of how to control the amount of reporting, which exists regardless of what is decided for the reporting resource.

**Issue #3-5:** Reporting resource

* Within updated HARQ-ACK codebook: Ericsson [3], Spreadtrum [7], (CATT [8]), Apple [13], Samsung [16]
  + No need to send earlier than HARQ-ACK: Spreadtrum [7]
  + Type 2 codebook only (too much information otherwise in Type 1): Ericsson [3]
  + Avoid modification to R16 HARQ-ACK codebook construction [16]
* Outside HARQ-ACK codebook: Ericsson [3], (Huawei [4]), (Spreadtrum [7]) (CATT [8]), LG [17], Nokia [19] (?)
  + May require less resources (control when and how often to report) [3]
  + Reuse current CSI framework [17]
  + On PUCCH only: Ericsson [3], Huawei [4]
  + Requires mapping to a reference PDSCH: Ericsson [3], LG [17]
  + On semi-statically configured resource: (CATT [8])

**Issue #3-6:** Triggering (in case it is outside of HARQ-ACK codebook):

* From DL DCI with new field: Huawei [4], Spreadtrum [7]
* Implicit from DL DCI: (CATT [8])
* Semi-static: (CATT [8])

**Issue #3-7**: Whether to report for every PDSCH, applicable conditions

* High-priority codebook [3][19], SPS [3], HARQ process [19], configured TBS [19], MCS threshold [19]
* Multiple PDSCH to one delta-MCS/CQI to reduce overhead [7]
* May use time window [8]
* Per-CC reporting [8]
* Dynamically indicated from RNTI of DL assignment [14]
* May take an average/filter from multiple PDSCHs [14], [16] (type 1 codebook)
* gNB indicate number of TBs for which UE provides delta-MCS value [16]
* Should not report for every ACK/NACK position in codebook [21]

Several companies discuss the number of bits and granularity of the new report:

**Issue #3-8:** Number of bits / mapping

* 1 additional bit [18][21]
* 2 bits including HARQ-ACK: [3][10]([16])
* 2 bits [8]
* Mapping depends on scheduled MCS range [11]
* Number of bits/mapping provided by higher layers: Samsung [16]

A few companies discuss whether the new report should target OLLA or retransmission:

**Issue #3-9**: Report for initial transmission, retransmission or both?

* At least for initial transmission (for OLLA): Nokia [19], Mediatek [21]
* Multi-level NACK (for retransmission) more important than multi-level ACK: ZTE [5]

A few companies discuss testability and definition aspects:

**Issue #3-10:** Testability, derivation of delta-CQI/MCS

* How to generate delta-MCS up to UE implementation (RAN4 tests to check that delta-MCS varies properly with varying SINR at fixed MCS): Ericsson [3]
* Delta CQI/MCS can be derived by UE implementation based on the ratio of failed parity checks in LDPC decoding. Throughput test and BLER test can be defined in RAN4: Qualcomm [10]
* Discuss exact method for deriving delta-CQI/MCS as it is related to possible RAN4 test cases: Nokia [19]

Other proposals/issues

* Both positive and negative delta-MCS (for positive ACK) to enable convergence: Ericsson [3]
* PDSCH is measurement resource: Spreadtrum [7] (moderator note: already agreed)
* May use multiple measurement resources: CATT [8]
* Support configuration of two MCS tables for PDSCH/PUSCH and indication of an MCS table by PI field in the DCI format: Samsung [16]
* Study impact on UE processing timeline [21][22], codebook construction procedure [21]
* Study impact of PDSCH symbols punctured or rate-matched [22], retransmissions [22]

## Observations for Topic #3

**Observations on new report types (Case 2)**

From the three first issues, it seems that there is majority view on the following aspects:

* The new report type should be supported;
* Delta-MCS is preferable to delta-CQI;
* The reference MCS for delta-MCS is the MCS applied to the scheduled PDSCH from which report is derived.

Moderator suggestion is to agree on the following proposal that includes a definition of delta-MCS. The definition suggested in [16] is used as a starting point (with some modifications given that how to determine BLER target needs to be further discussed).

**FL proposal 9.1-1**: **Support reporting of delta-MCS for a TB received with MCS index IMCS:**

* **delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
* **FFS: How to determine BLER target.**

For the issues related to reporting resource (within HARQ-ACK codebook or in separate resource), there does not seem to be clear majority in favor of either option at this point. Moderator suggestion is to gather additional input on this issue during this meeting.

**FL proposal 9.1-2**: **For reporting of delta-MCS, select between the two following options for the resource:**

* **Option 1: delta-MCS is reported as part of an extended HARQ-ACK codebook**
* **Option 2: delta-MCS is reported as a CSI report separate from HARQ-ACK codebook**
  + **FFS: Type of resource (e.g. PUCCH or higher layers)**
  + **Note: this does not preclude that the CSI report and HARQ-ACK codebook are multiplexed in same resource per multiplexing rules.**

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

TBD

**Question 3-1**: Please provide feedback if you would like to either (a) make correction in this moderator summary (such as evaluation results or company position) or (b) add your company position relative to the schemes listed in the above.

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

**Question 3-2**: Please indicate if FL proposal 9.1-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | This is just a short answer due to lack of time before the GTW. Hopefully we can have a more detailed discussion on this scheme after the GTW.  We don’t think that the UE needs to (or should) be made aware of the target BLER target is used by the gNB scheduler.  The gNB scheduler can basically select any target BLER, and it can also change it dynamically, e.g. for initial TX and re-TX or when serving eMBB and URLLC. Therefore, the UE algorithms to calculate the CQI could be become too complicated, since the UE would be required for to be able to calculate the best CQI for an infinite set of BLER values. Besides the implementation impact, there is also a testing impact and a possible constraint on the gNB scheduling flexibility.  We think that the UE should base the CQI calculation on the BLER values that are defined in Rel-16. This will keep the UE complexity lower. We should start with this assumption and then discuss the consequences, for example the required bitwidth for the delta-MCS report. |
| Nokia | No | We do not see any difference in MCS or CQI used in the reporting. It is just a report of SE value (with code rate and modulation). In that sense, reporting framework should first be discussed rather than the deciding CQI or MCS. |
| Samsung | Yes | Delta MCS is simpler as there is a reference MCS (of the received TB).  Although the gNB can vary the BLER per TB, there is no issue (otherwise, the CQI provided for a fixed 10% (or 0.001%) BLER wouldn’t work). A delta\_MCS of 2-3 bits and a granularity of delta\_MCS of ~3 entries from the MCS table can capture 2-3 orders of magnitude for BLER variations (no need/benefit/feasibility for delta\_MCS to have a granularity of a single MCS table entry). |
| Ericsson | Yes | In first bullet of the proposal, add: “delta-MCS” can be positive, negative, or zero” |
| Futurewei | No | Based on the performance evaluation results provided by multiple companies, there is little to none performance gain of Case 2-3 over baseline, and in some cases it results in performance loss. We should not support a scheme that doest not provide performance gain. |

**Question 3-3**: Please indicate if FL proposal 9.1-2 is acceptable, and your views on whether Option 1 or Option 2 is preferable.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | In our understanding Option 1 is out of scope. Delta-MCS cannot be part of the extended HARQ-QCK codebook, in this case it should be handled in AI 8.3.1.1 about HARQ enhancements. |
| Nokia | Partly | Generalize the reporting quantity and select first which framework is matching the best. We feel that CSI framework and HARQ framework are both suitable. But using CSi framework may be much easier than introducing a new mechanism. |
| Samsung | Yes | Prefer option 1. Option 2 does not work in general, is challenging for TDD, may result to duplicated signaling, complicate specifications, and there is no benefit from delta\_MCS if there is no one-to-one mapping of values with TBs (average delta\_MCS is practically useless). |
| Ericsson | Yes | Regarding Option 1 vs 2: we can accept either. Slightly prefer Option 1 due to simplicity and less standardization effort. |
| Futurewei | No | Please see our previous comment on Proposal 9.1-1. |

# Topic #4: Other enhancements

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

## Summary of issues for Topic #4

The following miscellaneous proposed enhancements do not neatly fall in one of the above categories:

* Specify CSI enhancements to better fit the needs of SPS PDSCH(s) [6]
* Split CSI report in multiple parts and multiplex as they become available on earliest PUSCH repetition occasion: Lenovo [16]
* Link MCS table to priority indicator: Samsung [16]

One contribution [3] discusses whether to support CSI feedback for PDCCH, and proposes to not support it in R17.

One contribution [5] discusses whether to support priority index 1 for P-CSI/SP-CSI on PUCCH, and proposes to not support it.

One contribution [17] proposes to discuss CSI priority between case 1/case 2/legacy reports.

## E-mail discussion (1st round) for Topic #4

TBD

# References

1. RP-201310 Revised WID: Enhanced IIoT and URLLC support for NR, Nokia, Nokia Shanghai Bell.
2. R1-2104199 CSI feedback enhancements for URLLC FUTUREWEI
3. R1-2104218 CSI Feedback Enhancements for IIoT/URLLC Ericsson
4. R1-2104263 CSI feedback enhancements Huawei, HiSilicon
5. R1-2104327 Discussion on CSI feedback enhancements for eURLLC ZTE
6. R1-2104354 CSI feedback enhancements for Rel-17 URLLC vivo
7. R1-2104421 Discussion on CSI feedback enhancements for Rel-17 URLLC Spreadtrum Communications
8. R1-2104513 CSI feedback enhancements CATT
9. R1-2104605 Discussion on CSI feeback enhancements for URLLC CMCC
10. R1-2104664 CSI enhancement for IOT and URLLC Qualcomm Incorporated
11. R1-2104803 CSI feedback enhancements for URLLC OPPO
12. R1-2104900 Selection of enhanced CSI feedback schemes Intel Corporation
13. R1-2105098 Views on eIIoT/URLLC CSI feedback enhancements Apple
14. R1-2105161 Considerations on CSI feedback enhancements Sony
15. R1-2105186 Discussion on CSI Feedback Enhancements Quectel, Langbo
16. R1-2105303 Improving MCS Selection for URLLC Samsung
17. R1-2105426 Discussion on CSI feedback enhancements for URLLC LG Electronics
18. R1-2105472 CSI feedback enhancements InterDigital, Inc.
19. R1-2105580 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
20. R1-2105694 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
21. R1-2105733 CSI feedback enhancements for URLLC MediaTek Inc.
22. R1-2105767 CSI feedback enhancements for URLLC/IIoT Lenovo, Motorola Mobility
23. R1-2102131, Feature lead summary#4 on CSI feedback enhancements for enhanced URLLC/IIoT, Moderator (InterDigital).
24. R1-2102749 Summary of additional discussions on CSI feedback enhancements for enhanced URLLC/IIoT after RAN1#104-e Moderator (InterDigital, Inc.)
25. R1-2103956, Feature lead summary #4 on CSI feedback enhancements for enhanced URLLC/IIoT, Moderator (InterDigital).
26. R1-2102745 CSI Feedback Enhancements for IIoT/URLLC Ericsson
27. R1-2105958 Selection of enhanced CSI feedback schemes Intel Corporation
28. R1-2106003 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell

# Appendix: Previous agreements

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 |