**3GPP TSG RAN WG1 #104-e R1-2101811**

**e-Meeting, January 25th – February 5th, 2020**

**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]:

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

In RAN1#102-bis, 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, 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.

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 #103-e

To be captured once agreement is made during this meeting

# Proposals for 1st GTW

New reporting Case 1:

A summary of proposals and evaluation results is available in section 8.1. Evaluation results are available for a subset of the Case 1 schemes identified in RAN1#103-e.

Considering the limited time available for the WI, it is proposed to narrow down the focus to schemes for which proponents show gains in % of satisfied users and/or latency distribution in at least one evaluation that follows baseline assumptions.

**FL proposal 8.1-1: For new reporting Case 1, continue study focusing on the following schemes:**

* **Case 1a: CQI/SINR statistics (mean, variance, etc.)**
* **Case 1c: CQI using maximum interference from multiple IMR**
* **Case 1c: CQI reporting considering the worst subbands**
* **Case 1e: UE updates CQI only based on previous RI/PMI to reduce processing time**

New reporting Case 2:

A summary of proposals and evaluation results is available in section 9.1. Evaluation results are available for a subset of the Case 2 schemes identified in RAN1#103-e.

Considering the limited time available for the WI, it is proposed to narrow down the focus to schemes that are supported by more than one company and for which evaluation results show gain in % satisfied UEs without very large increase of resource utilization.

**FL proposal 9.1-1: For new reporting Case 2, continue study focusing on the following schemes:**

* **For initial transmission: Soft-ACK**
* **For initial transmission: Report block error probability**
* **For retransmission: Report CQI/MCS with NACK**

New triggering methods:

A summary of proposals and evaluation results is available in section 7.1. Compared to RAN1#103-e, in general there does not seem to be much difference in company views. One company provided additional evaluation results, showing some gains in % of satisfied UE’s and resource utilization for A-CSI on PUCCH. In light of this, and since a major concern with A-CSI on PUCCH is the potential extra overhead on the DCI, it is suggested to check if the following could be agreeable.

**FL proposal 7.1-1: A-CSI on PUCCH can be triggered by DCI for DL assignment. At most [2] bits can be added to the DCI to support this.**

# 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: ZTE [3], Huawei [5], Ericsson [6], CATT [7], vivo [8], Spreadtrum [11], Panasonic [17], CMCC [18], NTT DOCOMO [22]
  + Better performance than P/SP-CSI on PUCCH due to more flexible feedback [3], because P/SP-CSI may not account for latest channel variations [5] and wideband P-CSI may not be accurate enough [18]
  + Trigger reporting based on traffic needs for sporadic traffic [3][5][18][22], or for periodic traffic when it is needed to improve performance [5]
  + Useful for retransmission when latency requirement is 4 ms [5] and/or subsequent TBs [5][7]
  + Less uplink overhead than A-CSI on PUSCH in DL-heavy scenarios, or SP-CSI/P-CSI with low periodicity [5][8][11][22]
  + More flexible triggering mechanism of A-CSI [6][11]
  + Lower PUCCH resource utilization than P/SP-CSI on PUCCH [6]
  + Transmission of single PDCCH transmission instead of two PDCCH with A-CSI on PUSCH [3][5][8][18]:
    - 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
  + A-CSI cannot be multiplexed on short PUSCH (1-2 symbols) for URLLC [17]
* Some concerns: Nokia [13], Sony [14], Lenovo [16], Apple [20]
  + Additional fields may be need in DCI for a functionality rarely requested [13]
  + How to trigger states, reporting time offset, PUCCH resource [13][16]
  + Possible impact to MAC CE [13]
  + May be useful if piggybacked with HARQ-ACK for early termination of PDSCH repetitions [14]
  + Need to decide whether PUCCH resource is same or different than HARQ-ACK [16]
  + Total number of activated trigger states needs to be limited [20]
* No: Mediatek [9], Intel [10], LG [15], Samsung [19]
  + P/SP-CSI reporting more suitable for factory scenario with periodic traffic [9]
  + P/SP-CSI reporting every 10 ms sufficient for AR/VR scenario with 22 ms coherence time [9][15][19]
  + No clear enhancement compared to A-CSI on PUSCH [9][10]
  + Does not address the problem of bursty interference which is the main performance issue [10]
  + If CSI and HARQ-ACK are combined in same resource, need to address codebook issues with missing assignments, need to delay HARQ-ACK compared to processing capability 2 and increased probability of error with larger payload [9]
  + Non-negligible specification efforts [10], e.g. complicated timeline [15], provision of additional resources for measurement and reporting and resolution of PUCCH/PUSCH overlapping [19]
  + Added overhead in DL assignments if new fields are required [10], wasting resource since no retransmission is needed ~99% of the time [9][10]
  + Resources for CSI in the UL may be limited by other URLLC transmissions [15]

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: ZTE [3], Qualcomm [21]
  + Good performance in terms of percentage of satisfied UEs [3]
  + Avoids excessive overhead of low CSI-RS periodicity/CSI report [21]
  + Can be used with semi-persistently scheduled PDSCH [21]
* No: Mediatek [9], Spreadtrum [11], Nokia [13], Sony [14], Panasonic [17]. Samsung [19]
  + May increase power consumption by requiring unnecessary A-CSI computation 99% of the time [9]
  + No benefit over (or worse than) DL DCI triggering [11][13], unnecessary overhead for most of the time [13][14], reduced network control over CSI reporting [13]
  + Would require blind decoding of PUCCH if CSI multiplexed with HARQ-ACK [17]
  + No CSI available for further TB transmission in case of ACK [17]

**Issue #1-3: Support A-CSI triggering on PUCCH by group DCI**

Several contributions [3][7][9][11][13][14][15] discuss potential support of triggering a A-CSI report by group DCI. However, none of these contributions support this option. The main reason is the inefficient use of group DCI resources since packet arrivals are not synchronous between UEs.

One company proposed to trigger CSI-RS or SRS when PDSCH is successfully received but with a low margin:

**Issue #1-4: Support CSI-RS/SRS triggering by low-margin ACK**

* Yes: Qualcomm [21]
  + To provide new report quickly when conditions start degrading [21]

One company proposed to support new CSI triggering method based on SP-CSI reporting:

**Issue #1-5: Support new CSI triggering method based on SP-CSI reporting**

* Yes: InterDigital [12]
  + To reduce PUCCH resource utilization of SP-CSI reporting on PUCCH

**Observations on new triggering methods.**

For A-CSI on PUCCH triggered by DL DCI:

* 9 companies support this, 4 companies do not support it and 4 do not provide a definitive view.
* Following evaluation results are available:
  + ZTE [3] provided additional evaluation results and observes the following gains:
    - 67% satisfied UEs vs 53% (if using A-CSI on PUSCH), or 50% (if using SP-CSI)
    - 2.9% resource utilization vs 3.1% (if using A-CSI on PUSCH) or 1.9% (if using SP-CSI)
  + Huawei [5] provides same results as in RAN1#103-e, observing gain of 37% in ratio of UEs satisfying 1 ms latency and 99.999% reliability at high load (500 p/s)
  + In RAN1#103-e, Samsung [23] observed loss from 90.2% to 84.6% in ratio of UEs satisfying 4 ms latency at 99.999% reliability, compared to SP-CSI on PUCCH

For A-CSI on PUCCH triggered by NACK

* 2 companies support this, 6 companies do not support it.
* Intel [10] observes very small gain in percentage of satisfied UEs (99.35% vs 99.25% for 99.99% reliability)

Considering the lower support and lack of positive evaluation results for “A-CSI on PUCCH triggered by NACK” (as well as no support for “A-CSI on PUCCH triggered by group DCI”), it is suggested to focus discussions on “A-CSI on PUCCH triggering by DCI for DL assignment” only.

For A-CSI on PUCCH triggered by DL DCI, evaluation results are mixed with 2 companies observing gains and 1 company not observing gain. Overhead is a major point of concern. On one hand, some companies think the overhead is reduced because it would avoid (1) frequent P/SP-CSI reports on PUCCH (2) extra PDCCH to trigger A-CSI on PUSCH and (3) possible extra PUSCH to carry the A-CSI. On the other hand, other companies think the overhead is increased because every DL DCI would need to carry extra field(s) to trigger the reporting and indicate a PUCCH resource.

The amount of extra overhead in the DL DCI depends on aspects that have not yet been discussed in detail. One possible way forward to progress is to agree on supporting A-CSI on PUCCH with condition that the DCI size does not increase by more than a certain number of bits.

**FL proposal 7.1-1: A-CSI on PUCCH can be triggered by DCI for DL assignment. At most [2] bits can be added to the DCI to support this.**

Several companies discuss more detailed aspects related to A-CSI report on PUCCH such as resource provision and timing indication. Such details could be addressed if/when there is consensus to support A-CSI on PUCCH.

**Issue #1-6: Resource/timing for A-CSI report**

* Option 1: DCI field (e.g. PRI)
  + ZTE [3], Huawei [5], Ericsson [6], Panasonic [17], NTT DOCOMO [22]
* Option 2: Next available periodic PUCCH resource
  + Ericsson [6]
* Option 3: Same resource as HARQ-ACK
  + ZTE [3], Huawei [5]
* Option 4: RRC
  + Panasonic [17], Qualcomm [21]
* Option 5: DCI indicates PUCCH resource or (RRC-configured) PUSCH
  + Vivo [8]

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

**Question 1-1:** Several companies provided evaluation results in RAN1#103-e and RAN1#104-e [3][5][23] for A-CSI on PUCCH, which show gain for [3][5] and no gain for [23]. Do you have any clarification question for these results? What is your view of the relevance of these results for the decision, considering assumptions used in the evaluation?

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| Company | Yes/No | Comments |
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**Question 1-2**: Would FL proposal 7.1-1 acceptable, considering available analysis and evaluation results? If not, would it become acceptable with different or additional condition(s)?

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| Company | Yes/No | Comments |
| Futurewei | Yes | Support FL proposal 7.1-1. |
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**Question 1-3**: If FL proposal 7.1-1 is not agreeable by the group, what way forward would you suggest? E.g. make decision in this meeting to not support? Continue evaluating until next meeting? Consider alternate triggering enhancements (such as enhanced SP-CSI on PUCCH [12] or enhanced CSI-RS/SRS triggering [21])?

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| Company | Yes/No | Comments |
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**Question 1-4**: Any other suggestion on how to make progress on new triggering methods?

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| Company | Yes/No | Comments |
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# 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

Several contributions propose new report types for CQI/SINR based on statistics or filtering from measurement resources. The reported quantity can correspond to a function (or filter) of a set of measurement samples of CQI/SINR, including an average, variance, percentile or prediction.

**Issue #2-1: Support new report type based on CQI/SINR statistics (Scheme 1a)**

* CQI/SINR statistics: Futurewei [2], Ericsson [6], Intel [10], Nokia [13]
  + Mitigate impact of interference variations [2][10], more accurate link adaptation for low target BLER and bursty interference [13]
  + Requires less UL overhead and complexity than network estimating variance from UE CSI reports[2][6][10]
  + Improves system resource utilization [6]
* Study: InterDigital [12], LG [15], Lenovo [16], Apple [20], Qualcomm [21]
  + Priority of new report type compared to existing types [15]
  + How to quantize, time window size, stationarity [16]
  + Need to clarify testability, reference CSI report [20]
  + Study benefit of predicted CSI [21]
* Concerns: ZTE [3], CATT [7], Vivo [8], LG [15], Samsung [19]
  + Performance gain may not compensate for additional overhead [3]
  + Performance gain depends on algorithm used at gNB. Not enough time. Should be discussed in MIMO SI/WI. [7]
  + Explicit reporting difficult to test [7]
  + Sub-optimal compared to subband CSI with short periodicity [8]
  + Large overhead considering URLLC traffic is sporadic [15]
  + Network can choose more conservative MCS [19]
  + Network can obtain information from individual CSI reports [19]

**Issue #2-2: Support new report type based on interference statistics (Scheme 1b)**

* Interference covariance matrix: Huawei [5]
  + Separate interference reporting helps to significantly improve performance of SU-MIMO and MU-MIMO schemes.
* Study: Intel [10], Lenovo [16], Qualcomm [21]
  + How much additional reference resources are required [16]
* No: CATT [7]
  + Performance gain may not compensate for additional overhead [3]
  + Performance gain depends on algorithm used at gNB. Not enough time. Should be discussed in MIMO SI/WI. [7]
  + Explicit reporting difficult to test [7]

**Issue #2-3: Support new report type based on modifying existing format (Scheme 1c)**

* CQI using maximum interference from multiple IMR: ZTE [3]
* Sub-band CSI report mode without differential operation: Huawei [5]
  + Reduces MCS prediction error [5]
* New differential CQI tables (3-bits): Mediatek [9], Samsung [19]
  + Reduces MCS prediction error [9]
* W-CQI excluding the worst subbands: Mediatek [9]
  + Reduces range of CQI offset for differential CQI [9]
* Worst-M subbands: Nokia [13], LG [15]
  + Significantly out-performs baseline SB reporting [13]
  + Much less overhead than full SB reporting [13]
  + Avoid weakest channel [15]
* Worst-best criteria for subband CQI report for URLLC [21]
* Concerns: Vivo [8], Samsung [19], Apple [20]
  + Worst-M CQI sub-optimal compared to subband CSI with short periodicity [8]
  + M-best subbands reporting allows for optimal scheduling [19]
  + For Worst-M, unclear if there is benefit if interference is not stationary [20]

**Issue #2-4: Support new reporting quantity related to CSI expiration time (1d)**

* Yes: Qualcomm [21]
  + Allows network to schedule conservatively if last CSI report is expired
* No: Samsung [19]
  + Network can obtain information from individual CQI reports [19]

**Issue #2-5: Support new reporting quantity with partial information update (1e)**

* UE updates CQI only based on previous RI/PMI to reduce processing time: Huawei [5], Vivo [8]
  + Update interference measurement only [5][8]
  + Update both channel and interference measurement [8]
* Report if measurement changes by some margin: Intel [10]
  + Saves CSI report payload
* Study: Lenovo [16]
  + Amount of reduction of processing time? [16]
* No: Samsung [19]
  + CQI-only reports already supported in R16 [19]

**Summary of evaluation results for new reporting Case 1**

ZTE [3], Huawei [5], Ericsson [6], Vivo [8], Mediatek [9], Intel [10], InterDigital [12], Nokia [13] provided system-level evaluation results for some Case 1 schemes. The results are summarized in the Table below.

Table . Summary of evaluation results for new reporting Case 1

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| --- | --- | --- | --- |
| **Source** | **Scheme** | **Scenario** | **Sample results**  **(Baseline result in [])** |
| ZTE [3] | Case 1a  Mean + stdev CQI | AR/VR | 31% satisfied UEs [50%]  2.9% RU [1.9%] |
| Ericsson [6] | Case 1a  Mean and variance SINR (wideband) | AR/VR  (mixed traffic) | 97.5% satisfied UEs [78.5%]  76% median RU [77%]  Baseline uses fixed backoff of 20 dB |
| Ericsson [6] | Case 1a  Mean and variance SINR (subband) | AR/VR  (mixed traffic) | 97.2% satisfied UEs [78.5%]  60% median RU [77%]  Baseline uses fixed backoff of 20 dB |
| Intel [10] | Case 1a  Mean and stdev SINR | AR/VR | 99.20% [99.25%] UEs for 99.99% reliability |
| InterDigital [12] | Case 1a  Mean + stdev CQI | AR/VR | 90.0% satisfied UEs [85.7%]  6.6 PRBs RU [6.7] |
| InterDigital [12] | Case 1a  Mean + stdev CQI | Factory | 100% satisfied UEs [53.3%]  2.9 PRBs RU [1.6] |
| Nokia [13] | Case 1a  Mean + stdev SINR | AR/VR | 1 ms 99.9999%-pct latency [2 ms]  5% RU [3%] |
| Nokia [13] | Case 1a  Mean + stdev SINR | Factory | ~1 ms 99.999%-pct latency [1 ms] |
| Huawei [5] | Case 1b  Interference covariance matrix | Factory  (non baseline) | 160 supported UEs [100]  38% RU [100%] |
| ZTE [3] | Case 1c  CQI using max interference from multiple IMR | AR/VR | 58% satisfied UEs [50%]  2.3% RU [1.9%] |
| Mediatek [9] | Case 1c  3-bit Diff-CQI | Factory | 0.4% of incorrect MCS [22%]  Baseline uses 2-bit D-CQI |
| Mediatek [9] | Case 1c  WB-CQI excludes 5 subbands | Factory | Reported enhanced wideband CQI better than baseline wideband CQI 62% of time |
| Intel [10] | Case 1c  Full SB CQI | AR/VR | 99.05% [99.25%] UEs for 99.99% reliability |
| Nokia [13] | Case 1c  Full SB CQI | AR/VR | 1 ms 99.9999%-pct latency [2 ms]  6% RU [3%]  Baseline SB CQI, 2-bit |
| Nokia [13] | Case 1c  Worst-2 CQI | AR/VR | 1 ms 99.9999%-pct latency [2 ms]  5% RU [3%] |
| Nokia [13] | Case 1c  Worst-2 CQI | Factory | ~1 ms 99.999%-pct latency [1 ms] |
| Vivo [8] | Case 1e  Full CSI every 40 ms  Update CQI (only) based on IMR every 10 ms | AR/VR | 71% satisfied UEs [67%, period 40 ms]/[98%, period 10 ms]  56% RU [77%, period 40 ms]/[48%, period 10 ms]  Baseline uses full CSI recalculation |
| Vivo [8] | Case 1e  Full CSI every 40 ms  Update CQI based on CSI-RS and IMR every 10 ms | AR/VR | 89% satisfied UEs [67%, period 40 ms]/[98%, period 10 ms]  52% RU [77%, period 40 ms]/[48%, period 10 ms]  Baseline uses full CSI recalculation |

**Observations on new report types (Case 1)**

* Evaluation results showing percentage of users satisfying reliability and latency requirements (Option 1) or latency statistics using baseline assumptions are available for the following schemes:
  + Case 1a: Mean + stdev of CQI/SINR [3][6][10][12][13]
    - [6][12][13] show gain in % of satisfied UEs, resource utilization and/or latency statistics
    - [3][10] show loss or small gain
  + Case 1c: CQI using maximum interference from multiple IMR [3]
    - [3] shows gain in % of satisfied users
  + Case 1c: Worst-2 CQI [13]
    - [13] shows gain in latency statistics
  + Case 1c: Full SB-CQI (disable differential SB-CQI) [10][13]
    - [10] shows small loss in % of satisfied UEs
    - [13] shows gain in latency statistics
  + Case 1e: Partial CQI update [8]
    - [8] shows limited loss in % of satisfied UEs and resource utilization compared to full CSI recalculation in every CQI report.
* Evaluation results are available for the following schemes, but do not show the reliability/latency metric or do not follow the agreed baseline assumptions:
  + Case 1b: Interference covariance matrix [5]
  + Case 1c: 3-bits differential CQI [9]
  + Case 1c: WB-CQI excluding 5 worst sub-bands [9]
* No evaluation result is available for the following schemes:
  + Case 1a: Predicted CSI
  + Case 1c: Worst-best criteria for subband CQI
  + Case 1d: CSI expiration time

Considering the limited time available for the WI, it is proposed to narrow down the focus to schemes for which proponents show gains in % of satisfied users and/or latency distribution in at least one evaluation that follows baseline assumptions.

**FL proposal 8.1-1: For new reporting Case 1, continue study focusing on the following schemes:**

* **Case 1a: CQI/SINR statistics (mean, variance, etc.)**
* **Case 1c: CQI using maximum interference from multiple IMR**
* **Case 1c: CQI reporting considering the worst subbands**
* **Case 1e: UE updates CQI only based on previous RI/PMI to reduce processing time**

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

As explained in the above and during GTW session, FL proposal 8.1-1 is to prioritize further study on schemes for available evaluations show gain in terms of UE satisfaction/latency metric in a scenario following baseline assumptions agreed in RAN1#102-e. This is considering the available time since RAN1#102-e (>4 months) and the limited time for R17.

From the submitted contributions, one can also observe that a lot of the schemes that would be down-selected seem to have very limited support, typically having been proposed by the same company for 2-3 meetings without gathering interest from additional companies.

**Question 2-1**: Do you think RAN1 should spend additional efforts on a Case 1 scheme not listed under FL proposal 8.1-1? (Please answer even if you are not proponent). If yes and you are proponent, please explain how you would convince additional companies considering that these schemes were already proposed in earlier meetings without gathering more support.

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| Company | Yes/No | Comments |
| Futurewei |  | In our contribution R1-2100037, simulation results show that that interference observed at the UE varies significantly over time (e.g., > 6 dB with 10% probability when the time difference between two observations is >= 3 TTIs). Reporting interference statistics or CQI/SINR statistics can help gNB mitigate the impact of large variation of interference. Therefore, we would like to modify Case 1a as follows:   * **Case 1a: CQI/SINR/Interference statistics (mean, variance, etc.)** |
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**Question 2-2**: Do you have any question for clarification, or any comment, on the available evaluation results?

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| Company | Yes/No | Comments |
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**Question 2-3**: Do you think the evaluation methodology and assumptions for the schemes are adequate? If not, do you have any suggestion on how to update it to (more) fairly assess the potential benefit of the proposed schemes?

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| Company | Yes/No | Comments |
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**Question 2-4**: Any other suggestion on how to make progress on Case 1 new reporting?

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| Company | Yes/No | Comments |
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# Topic #3: New reporting (Case 2)

## Summary of issues for Topic #3

For Case 2 new reporting, RAN1 agreed to continue studying with focus on new reporting type based on PDSCH decoding for OLLA performance enhancement. Many companies discuss and evaluate potential benefits of such schemes.

The new reporting type could target improved MCS selection for the initial transmission, or target improved MCS selection for the re-transmission in case of NACK. One company [21] noted that these could be associated with different timelines, since in the latter case (retransmission) the report needs to be transmitted urgently but not in the former case (initial transmission).

**Issue #3-1: Support new reporting for initial transmission**

* Supportive/study further: ZTE [3], Oppo [4], Ericsson [6], CATT [7], Mediatek [9], InterDigital [12], Nokia [13], Sony [14]
  + Delta SINR quantized as 3-bit feedback [3]
  + MCS offset compared with last PDSCH [4][7]
    - Concern: limited sampling resolution [9]
  + Soft-ACK (low margin or high margin) [6][9][12][14]
    - Measurement based on LDPC iterations [6]
    - Related to estimated TB error probability [9]
    - Slow Soft-ACK – reporting may not be same resource as HARQ-ACK [12]
  + Estimated TB error probability [13]
    - Derived from LLR [13]
* Concerns/questions: Futurewei [2], Huawei [5], Vivo [8], LG [15], Lenovo [16], Samsung [19]
  + Additional information does not help with bursty interference [2][19]
  + Not need if accurate CSI can be acquired, should be under CSI framework [5]
  + Sub-optimal compared to subband CSI with short periodicity [8]
  + How to translate decoding result in measurement quantity, which PDSCH is considered, priority of new report type compared to existing report types [15]
  + Whether additional feedback is always sent, jointly or separately encoded with HARQ-ACK, impact on computation delay/PCU [16]
  + Testing impacts, potential benefits are unclear [19]

**Issue #3-2: Support new reporting for retransmission**

* Support/study further: ZTE [3], Sony [14], Apple [20], Qualcomm [21]
  + Multi-level NACK feedback based on Delta SINR [3]
  + Instantaneous MCS/CQI feedback or delta MCS [3][21]
  + Recommended HARQ redundancy version sequence [20]
  + Report PDSCH decoding failure reason [14][21]
* Concerns: Intel [10]
  + Initial transmission is quite robust (.001%-1%) which limits possible gains [10]

**Summary of evaluation results for new reporting Case 2**

ZTE [3], Intel [10], InterDigital [12], Nokia [13], Qualcomm [21] provided system-level evaluation results for some Case 2 schemes. The results are summarized in the Table below.

Table . Summary of evaluation results for new reporting Case 2

|  |  |  |  |
| --- | --- | --- | --- |
| **Source** | **Scheme** | **Scenario** | **Sample results**  **(Baseline result in [])** |
| **New reporting for initial transmission** | | | |
| ZTE [3] | Delta SINR | AR/VR | 61% satisfied UEs [50%]  2.3% RU [1.9%] |
| InterDigital [12] | Delta SINR | AR/VR | 99.6% satisfied UEs [85.7%]  16.2 PRBs RU [6.7] |
| InterDigital [12] | Delta SINR | Factory | 100% satisfied UEs [53.3%]  3.0 PRBs RU [1.6] |
| InterDigital [12] | EP | AR/VR | 90.9% satisfied UEs [85.7%]  7.1 PRBs RU [6.7] |
| InterDigital [12] | EP | Factory | 96.1% satisfied UEs [53.3%]  2.2 PRBs RU [1.6] |
| InterDigital [12] | Soft-ACK (slow) | AR/VR | 93.8% satisfied UEs [85.7%]  7.8 PRBs RU [6.7] |
| InterDigital [12] | Soft-ACK (slow) | Factory | 100% satisfied UEs [53.3%]  2.4 PRBs RU [1.6] |
| Nokia [13] | EP | AR/VR | 5 ms 99.9999%-pct latency [2 ms]  20% RU [3%] |
| Nokia [13] | EP +  Case 1a: Mean + stdev SINR | AR/VR | 1 ms 99.9999%-pct latency [2 ms]  6% RU [3%] |
| Nokia [13] | EP | Factory | ~1 ms 99.999%-pct latency [1 ms] |
| Nokia [13] | EP  Case 1a: Mean + stdev SINR | Factory | ~1 ms 99.999%-pct latency [1 ms] |
| **New reporting for retransmission** | | | |
| ZTE [3] | Retransmission: Delta SINR (3-bit) | AR/VR | 94% satisfied UEs [50%]  33% RU [1.9%] |
| ZTE [3] | Retransmission: Delta MCS (3-bit) | AR/VR | 60% satisfied UEs [50%]  1.9% RU [1.9%] |
| Intel [10] | Retransmission: report CSI | AR/VR | 99.35% [99.25%] UEs for 99.99% reliability |
| Qualcomm [21] | Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 20 URLLC UEs) | 100% satisfied UEs [100%]  3471 RBs for 2nd Tx [5255] |
| Qualcomm [21] | Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 20 URLLC UEs) | 100% satisfied UEs [100%]  5878 RBs for 2nd Tx [7545] |

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

* Evaluation results showing percentage of users satisfying reliability and latency requirements (Option 1) or latency statistics using baseline assumptions are available for the following schemes:
  + For initial transmission: Delta-SINR [3][12]
    - [3][12] show gain in % of satisfied UEs with higher [3] or much higher [12] resource utilization
  + For initial transmission: BLEP [12][13]
    - [12] shows gain in % of satisfied users, with slightly higher resource utilization
    - [13] shows loss in % of satisfied users in AR/VR scenario unless used in combination with Case 1a
  + For initial transmission: Soft-ACK (slow) [12]
    - [12] shows gain in % of satisfied users, with higher resource utilization
  + For retransmission: Delta-SINR [3]
    - [3] shows gain in % of satisfied UEs with much higher resource utilization
  + For retransmission: CQI/MCS [3][10][21]
    - [3] shows gain in % of satisfied UEs with same resource utilization
    - [10] shows small gain in % of satisfied UEs
    - [21] shows reduction of resource utilization for the retransmissions
* No evaluation result is available for the following schemes:
  + Initial transmission: MCS offset compared with last PDSCH
  + Retransmission: Recommended HARQ redundancy version sequence
  + Retransmission: Report PDSCH decoding failure reason

Considering the limited time available for the WI, it is proposed to narrow down the focus to schemes that are supported by more than one company and for which evaluation results show gain in % satisfied UEs without very large increase of resource utilization.

**FL proposal 9.1-1: For new reporting Case 2, continue study focusing on the following schemes:**

* **For initial transmission: Soft-ACK**
* **For initial transmission: Report block error probability**
* **For retransmission: Report CQI/MCS with NACK**

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

As explained in the above, FL proposal 9.1-1 is to prioritize further study on schemes for available evaluations show gain in terms of UE satisfaction/latency metric in a scenario following baseline assumptions agreed in RAN1#102-e. This is considering the available time since RAN1#102-e (>4 months) and the limited time for R17.

From the submitted contributions, one can also observe that a lot of the schemes that would be down-selected seem to have very limited support, typically having been proposed by the same company for 2-3 meetings without gathering interest from additional companies.

**Question 3-1**:Do you think RAN1 should spend additional efforts on a Case 2 scheme not listed under FL proposal 9.1-1? (Please answer even if you are not proponent). If yes and you are proponent, please explain how you would convince additional companies considering that these schemes were already proposed in earlier meetings without gathering more support.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | It is unclear to us how the new reporting quantities in new reporting Case 2 could provide information about the interference at future PDCCH/PDSCH reception time due to the large variation of interference, and how the new reporting quantities can help gNB improve MCS selection for the future PDCCH/PDSCH transmission considering the low latency requirements in URLLC. |
|  |  |  |
|  |  |  |

**Question 3-2**: Do you have any question for clarification, or any comment, on the available evaluation results?

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

**Question 3-3**: Do you think the evaluation methodology and assumptions for the schemes are adequate? If not, do you have any suggestion on how to update it to (more) fairly assess the potential benefit of the proposed schemes?

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

**Question 3-4**: Any other suggestion on how to make progress on Case 2 new reporting?

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

# Topic #4: Other enhancements

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

## Summary of issues for Topic #4

2 companies propose to enhance CSI feedback for PDCCH for R17 URLLC.

**Issue #4-1: Support CSI feedback for PDCCH**

* Support: Samsung [19], Qualcomm [21]
  + Motivations
    - PDCCH needs to be at least as reliable as PDSCH [19][21]
    - OLLA not possible for PDCCH because gNB cannot distinguish between NACK and DTX for multi-bit HARQ-ACK [19]
    - CSI for PDCCH cannot be derived from CSI for PDSCH as coding scheme, resource (coreset), TCI state, DMRS configuration are different [21]
    - Increased PDCCH blocking/overhead if PDCCH is scheduled too conservatively [21]
  + Candidate solutions
    - 1-2 bits in a Type-2 HARQ-ACK codebook to indicate a number of NACK values [19]
    - Tri-state HARQ-ACK [21]
* No support: Ericsson [6], Intel [10]
  + Can use rank1 restriction which is anyway useful for URLLC [6]
  + Does not need to be more accurate than PDSCH link adaptation for small allocation [6]
  + Main challenge is bursty interference which can be addressed by statistical CSI [6]
  + Code rate / resource adaptation for PDCCH is very coarse [6][10]
  + RSRP, L1-SINR, DTX of HARQ-ACK can be used [10]

**Observations for CSI feedback for PDCCH**

* 2 companies see the benefit of supporting CSI feedback for PDCCH as ensuring URLLC reliability while avoiding too conservative PDCCH resource allocation.
* 2 companies think that existing mechanisms (e.g. CSI feedback, DTX, L3 measurements) are sufficient and/or that statistical CSI would be more helpful for PDCCH link adaptation.
* No evaluation result is available for the proposed enhancements.
* In RAN1#103-e, 13 companies supported proposal to not further study this.

Several companies propose to support configuration of high-priority for P-CSI/SP-CSI or A-CSI on PUCCH (if supported). During RAN1#102-e, it was suggested that this issue could be discussed in AI 8.3.3.

**Issue #4-2: Support priority index 1 for P-CSI/SP-CSI/A-CSI on PUCCH**

* Support for P-CSI/SP-CSI:
  + Yes: Intel [10]
  + No: CATT [7], ZTE [3]
* Support for A-CSI (if supported):
  + Yes: ZTE [3], CATT [7], Panasonic [17], NTT DOCOMO [22]

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

* Reduce CQI report content and define new CQI report types to reduce CSI processing time [4]
* Specify CSI enhancements to better fit the needs of SPS PDSCH(s) [6]
* Enhancements for interference measurements, time restriction and resource configuration: Nokia [13]
* Reconfigure definition of CSI reference resource to better align with typical URLLC payload sizes: Nokia [13]
* Split CSI report in multiple parts and multiplex as they become available: Lenovo [16]
* Link MCS table to priority indicator: Samsung [19]
* UE request for CSI measurement to update CSI for a new Tx-Rx beam pair: Qualcomm [21]
* A-CSI on PUCCH multiplexed on PUSCH repetition type B: NTT DOCOMO [22]

## 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. R1-2100037 CSI feedback enhancements for URLLC FUTUREWEI
3. R1-2100102 Discussion on CSI feedback enhancements for eURLLC ZTE
4. R1-2100182 CSI feedback enhancements for URLLC OPPO
5. R1-2100227 CSI feedback enhancements Huawei, HiSilicon
6. R1-2100269 CSI Feedback Enhancements for IIoT/URLLC Ericsson
7. R1-2100377 CSI feedback enhancements CATT
8. R1-2100437 CSI feedback enhancements for Rel-17 URLLC vivo
9. R1-2100575 CSI feedback enhancements for URLLC MediaTek Inc.
10. R1-2100650 CSI feedback enhancements for URLLC/IIoT Intel Corporation
11. R1-2100790 Discussion on CSI feedback enhancements Spreadtrum Communications
12. R1-2100830 CSI feedback enhancements InterDigital, Inc.
13. R1-2100835 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
14. R1-2100856 Considerations on CSI feedback enhancements Sony
15. R1-2100881 Discussion on CSI feedback enhancements for URLLC LG Electronics
16. R1-2100994 CSI feedback enhancements for IIoT/URLLC Lenovo, Motorola Mobility
17. R1-2101014 Discussion on CSI feedback enhancements Panasonic Corporation
18. R1-2101040 Discussion on CSI feedback enhancements for URLLC CMCC
19. R1-2101202 Improving MCS Selection for URLLC Samsung
20. R1-2101379 Views on CSI feedback enhancements Apple
21. R1-2101460 CSI enhancement for IOT and URLLC Qualcomm Incorporated
22. R1-2101613 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
23. R1-2008160 CSI feedback enhancements for URLLC Samsung

# Appendix: Previous agreements

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 |