**3GPP TSG RAN WG1 #102-e R1-200xxxx**

**e-Meeting, August 17th – August 28th, 2020**

**Agenda Item: 8.3.1.2**

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

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

**Document for: Discussion and Decision**

# Introduction

Per chairman’s guidance, two check points for the e-mail discussions were planned as below:

[102-e-NR-IIOT\_URLLC\_enh-02] Email discussion/approval – Moonil (IDC)

* By 8/21 – high priority
* By 8/27 – medium

The summary of the first round of e-mail discussions were captured in this document.

* Section 2 includes the proposed conclusions and/or agreements based on the inputs from the companies
* Section 3 captured the priority discussion for the identified issues to focus on high/medium priority topics this meeting
* Sections 4 to 6 includes summary of tdocs, discussed issues, and inputs from companies. Also, proposed conclusions and agreements are captured in each issue.

# Proposals based on e-mail discussions

## From the first round of e-mail discussions:

The details of the summary are in the corresponding section for each issue.

**General issues – Issues #2-2 and #3-2 (high priority)**

It is observed that the subband differential CQI feedback enhancement is the issue the majority number of companies think it is not needed or lower priority (Issue #2-2).

The CSI feedback enhancement for Multi-TRP transmission is currently under discussion in Rel-17 FeMIMO WI. All companies responded seem to be ok not to discuss this topic under this WI.

Considering that there are a lot of new CSI enhancement schemes which have not been discussed in previous releases under URLLC, the performance evaluation of the proposed schemes with common assumptions should be performed to make progress. As TR 38.824 already includes the evaluation assumptions for URLLC, we can select a subset of scenarios/assumptions to be used for the CSI enhancement scheme evaluation with some updates if needed.

**Proposed conclusion:**

* Discussion on enhancement of subband differential CQI feedback is deprioritized under IIoT/URLLC enhancement WI
* CSI feedback enhancement for Multi-TRP transmission is not discussed further under IIoT/URLLC enhancement WI

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| **Company** | **Comments** |
| MediaTek | We object to deprioritizing the discussion on enhancement of subband differential CQI feedback.  It is very early to deprioritize this topic given the interest from companies, and the fact there was no technical discussion on the gains for these enhancements. Looking at the summary of Issue#2-2, there are 5 companies want to study, and 8 companies think there is a need for further study and evaluations. So, we believe proposed conclusion on differential CQI is not properly reflecting the interest from companies.  We support deprioritizing feedback enhancement for Multi-TRP under IIoT/URLLC enhancement WI. |
| Ericsson | * For subband CQI: this should be left open if changes are needed for the purpose of CSI computation delay reduction. * For multi-TRP CSI: we don’t agree, unless it is confirmed that Rel-17 eMIMO handles the CSI enhancement of URLLC-oritented multi-TRP. |

**Proposed conclusion:**

* Discuss on evaluation methodologies to be commonly used for study and evaluation of CSI enhancement schemes proposed
  + Reuse the assumptions in TR 38.824 as baseline

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| **Company** | **Comments** |
| MediaTek | We agree on discussing the evaluation methodologies, but we don’t think it will be feasible to have common evaluation approach for all the enhancements.  Regarding “Reuse the assumptions in TR 38.824 as baseline”, is this referring to the SLS/LLS simulation assumption? If so, then we are fine with that. |
| Ericsson | It should be clarified what schemes are to be evaluated.  Some enhancements do not require evaluation, e.g., reduction of CSI computation delay. |

**Issue #1-1 (high priority)**

This issue has been discussed from previous releases. A limited number of evaluations of the A-CSI on PUCCH during SI phase and the evaluations were from different scenarios and/or assumptions. A couple of companies raised concerns that the evaluation with common assumption should be conducted before we move forward as those companies are still questioning the performance benefit of A-CSI on PUCCH.

**Proposed conclusion:**

* Companies are encouraged to study and evaluate A-CSI on PUCCH scheme considering performance, specification impact, and signaling/RS overhead

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| **Company** | **Comments** |
| MediaTek | Fine with the proposal. |
| Ericsson | OK with the proposal |

**Issue #1-2 (high priority)**

Most of companies (9) who support A-CSI on PUCCH also support option-1 as a triggering method. But, after e-mail discussion, there are still many companies (10) want to keep the options as it is until the A-CSI on PUCCH issue is resolved. We can list these options for the evaluation of A-CSI on PUCCH.

**Proposed agreement:**

* The following three triggering options can be considered for the study/evaluation of A-CSI on PUCCH:
  + Option-1: DL DCI
  + Option-2: group-common DCI
  + Option-3: NACK of a PDSCH (without DCI triggering)

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| **Company** | **Comments** |
| MediaTek | We don’t think there is a need for this proposal. The pros and cons of A-CSI on PUCCH need to be evaluated first, then the triggering mechanisms can be discussed later. |
| Ericsson | This should wait for the study described in previous proposal (“study and evaluate A-CSI on PUCCH scheme considering performance, specification impact, and signaling/RS overhead”) |

**Issue #2-1 (high priority)**

New CSI report type(s) get supported by majority companies based on the e-mail discussion but the proposals from supporting companies are quite diverging at this point and no evaluation was conducted for those. Also, the details of the proposals are needed for evaluation.

**Proposed conclusion:**

* Companies are encouraged to study and evaluate new CSI report type(s) in terms of technical benefit and specification impacts.
  + For performance evaluation, each proponent needs to provide detailed assumption of the proposed new CSI report type(s), including
    - reporting values
    - measurement resource
    - how to use the reported new CSI report type(s) at the gNB scheduler

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| **Company** | **Comments** |
| MediaTek | Fine with the proposal. |
| Ericsson | Support the proposal |

**Issue #1-5 (Medium priority)**

**Suggestion for discussion:**

* Study further on CSI processing time reduction of A-CSI reporting in terms of technical benefit and feasibility for both PUCCH and PUSCH

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| **Company** | **Comments** |
| MediaTek | Fine with the proposal. |
| Ericsson | Support the proposal |

**Issue #1-6 (Medium priority)**

**Suggestion for discussion:**

* Study further on configuring priority index 1 for P/SP-CSI and A-CSI on PUCCH (if supported) in terms of the technical benefit and specification impacts

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| **Company** | **Comments** |
| MediaTek | This could be postponed after the discussion on A-CSI on PUCCH progress. It will have very limited benefit when considering only P/SP-CSI on PUCCH. |
| Ericsson | Even if this is to be studied, it belongs to the intra-UE multiplexing/prioritization AI (AI 8.3.3). |

**Issue #3-1 (Medium priority)**

Similar to the issue 2-1, this issue also supported by majority companies, but the proposals are quite diverging. We need to identify the options with detailed assumption for evaluation.

**Proposed conclusion:**

* Companies are encouraged to study and evaluate additional information to be bundled to HARQ feedback in terms of technical benefit and specification impacts.
  + For performance evaluation,
    - each proponent provides detailed assumption of the proposed additional information to be bundled to HARQ feedback, including
      * how scheduler uses the additional information for retransmission and/or sub-sequent transmission

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| **Company** | **Comments** |
| MediaTek | Fine with the conclusion |
| Ericsson | Support the proposal |

**Issue #3-3 (Medium priority)**

**Suggestion for discussion:**

* Study further on CSI feedback for PDCCH including
  + Identify the options
  + Evaluate the performance gain and specification impact of the identified option

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| **Company** | **Comments** |
| MediaTek | We think this can be deprioritized given the amount of CSI enhancements in this WI. |
| Ericsson | We also consider this low priority |

**Issue #1-3 and Issue #1-4 (low priority)**

These issues are next level of details when/if A-CSI on PUCCH is agreed. Therefore, to save time, it is proposed not to discuss this issue until the A-CSI on PUCCH issue is resolved.

**Proposed conclusion:**

* Additional conditions for A-CSI reporting on PUCCH and PUCCH resource determination for A-CSI on PUCCH to be discussed if/when RAN1 agrees to support A-CSI on PUCCH.

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| **Company** | **Comments** |
| MediaTek | No need for this proposal at this stage. |
| Ericsson | This should wait, as commented by many companies. |

# Priority of the issues

**List of the issues identified:**

**Issue #1-1: Support aperiodic CSI report on PUCCH**

**Issue #1-2: Triggering method of aperiodic CSI report on PUCCH**

**Issue #1-3: Additional conditions for A-CSI reporting on PUCCH triggered by DL DCI**

**Issue #1-4: PUCCH resource determination for A-CSI on PUCCH**

**Issue #1-5: Reduction of CSI computation time**

**Issue #1-6: Priority applicable to P/SP-CSI on PUCCH and (if supported) A-CSI on PUCCH**

**Issue #2-1: introduce new CSI report type(s)**

**Issue #2-2: Need for enhancing accuracy of sub-band differential CQI feedback**

**Issue #3-1: Need for additional information bundled to HARQ-ACK**

**Issue #3-2: Enhanced CSI reporting for multi-TRP scenarios**

**Issue #3-3: CSI feedback for PDCCH enhancement**

**Summary:**

The number in the table is the number of companies supporting the issue for the given priority

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|  | **High** | **Medium** | **Low** |
| **Issue #1-1** | **8** | **2** | **5** |
| **Issue #1-2** | **6** | **1** | **7** |
| **Issue #1-3** | **0** | **5** | **10** |
| **Issue #1-4** | **3** | **4** | **8** |
| **Issue #1-5** | **2** | **7** | **7** |
| **Issue #1-6** | **2** | **6** | **8** |
| **Issue #2-1** | **7** | **6** | **3** |
| **Issue #2-2** | **1** | **5** | **8** |
| **Issue #3-1** | **5** | **4** | **8** |
| **Issue #3-2** | **0** | **1** | **12** |
| **Issue #3-3** | **5** | **1** | **10** |

**FL suggestion for the issue priority for discussion**

Issue priority:

* High: 1-1, 1-2, 2-1
* Medium: 1-5, 1-6, 3-1
* Low: 1-3, 1-4, 2-2, 3-3

Note:

* High priority issue was determined if High > 5
* Medium priority issue was determined if High+Medium >7
* Low priority issue was determined otherwise
* Issues #1-3 and #1-4 can be discussed after the Issue #1-1 is resolved as those issues are next level of details if Issue #1-1 is agreed
* Issue #3-2 doesn’t need to be discussed further in this WI to avoid duplicated discussion in multiple WIs as it is under discussion in FeMIMO WI already
* Issue #3-3 is added as a reasonable number of companies supported (see Question #11)

**Please provide the company’s view on the priority of the issues listed above:**

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| **Company** | **Priority of the issues** | **Comments** |
| Sony | High: 1-1, 2-1,  Medium: 2-2, 3-1  Low: 1-2, 1-3, 1-4, 1-5, 1-6, 3-2 | Consider feedback for PDCCH. |
| Samsung | High: 1-6  Medium: 2-1  Low: Everything else above |  |
| FUTUREWEI | High: 2-1  Medium: 1-1, 3-2, 2-2  Low: 1-2, 1-3, 1-4, 1-5, 1-6, 3-1 | Support new CSI report type(s) such as report of channel/interference statistics to allow for more accurate MCS selection. |
| InterDigital | High: 1-1, 1-2, 2-1, 3-1  Medium: 1-3, 1-5, 2-2  Low: 1-4, 1-6, 3-2 | Feedback for PDCCH (Medium) |
| Qualcomm | High: 3-1, feedback for PDCCH  Medium: 1-6,  Low: 1-1, 1-2,1-3,1-4,1-5, 2-1, 2-2, 3-2 | We support to study channel state information feedback for PDCCH. |
| DOCOMO | High: 1-1, 1-2  Medium: 1-3, 1-4, 1-5, 2-1  Low: 1-6, 3-1 | Low: Feedback for PDCCH |
| HW/HiSi | High: 1-1, 1-2, 2-2  Medium: 1-3, 1-4, 2-1,1-5  Low: 1-6, 3-1, 3-2 | For 1-3 and 1-4, we think they are very important, but during this phase not as important as 1-1 and 1-2. We would appreciate an exchange of views on 1-3 and 1-4 and maybe a list of candidate methods, however. |
| Panasonic | High: 1-1, 1-2, 1-4, 1-6  Medium: 1-3, 1-5, 2-1, 2-2, 3-1  Low: 3-2 |  |
| Intel | High: 2-1  Medium: 1-6  Low: 1-5 | It seems details of A-CSI on PUCCH got many lines in the issue list. We first need to decide general support of A-CSI on PUCCH in order to go to the details.  In our view w/o analyzing and introducing new CSI measurements/reporting, other discussed mechanisms could not combat bursty interference dominated in URLLC scenarios, |
| vivo | High: 1-5, evaluation methodology/assumptions  Medium: 1-1, 1-2, 1-4, 1-6, 2-1  Low: 1-3, 2-2, 3-1, 3-2 | Currently, the timeline required for CSI computation is longer than the PDSCH processing. Whether and how to reduce the CSI computation time needs to be discussed with high priority.  The potential gains by CSI enhancements need to be further clarified. So we suggest to discuss how to evaluate the performance and identify the benefits for the enhancements. |
| CMCC | High：1-1,1-2,1-4  Medium：1-5,1-6,2-1,3-1  Low:1-3,2-2,3-2 |  |
| NEC | High:1-1, 1-2,2-1  Medium:1-3, 1-4, 1-5,1-6, 2-2  Low:3-1 | 3-2 should be left for handling in Rel-17 FeMIMO WI |
| CATT | High: 1-1, 1-2, 1-4  Medium: 1-5, 2-1  Low: 1-3, 1-6, 2-2, 3-1, 3-2 |  |
| Lenovo, Motorola Mobility | High: 1-5  Medium: 1-6  Low: the rest | 1-5: In our view, CSI computation time reduction is the most straight-forward way of getting fresh MCS. We are open to discuss different ways of achieving CSI computation reduction (e.g., more capable UE, simplified CSI report, etc.)  1-1 to 1-4:   * A-CSI trigger by DL-DCI may be beneficial for reducing PDCCH blocking (especially in DL heavy traffic scenario), however, it is not clear to us if it leads to more accurate MCS selection compared to using existing A-CSI triggering via UL-DCI. * CSI computation delay requirements should be first decided before considering whether to introduce A-CSI trigger by a DL-DCI.   1-6: makes sense to us for collision handling  The rest:   * Although many of these proposals are quite interesting, many of them can be discussed in a more general framework than the URLLC WI.   3-2: can be discussed in the MIMO AI. |
| ZTE | High: 3-1,1-1, 1-2, 1-3, 1-4  Medium: 1-6  Low:1-5, 2-1, 2-2, 3-2 | For 1-3, we think the triggering mechanism should be first considered, then based on the triggering mechanism, other issues can be considered, so 1-3 is also very important. |
| Sharp | High: 1-5,2-1  Medium: 1-1, 1-6, 2-2, 3-1  Low: 1-2, 1-3, 1-4, 3-2 |  |
| Apple | High: 3-1  Low: the rest |  |
| Nokia/NSB | High: 2-1, 3-1  Low: remaining ones |  |
| MediaTek | High: 2-2, 2-1  Medium: 1-5  Low: the rest |  |
| Ericsson | High: 1-5, 2-1, 3-1, 3-2,  Low: 1-6, |  |

# Enhancements for faster CSI reporting

In this section, we provide summary of contributions related to the enhancements for faster CSI reporting.

## A-CSI on PUCCH

### Issue #1-1

**Issue #1-1: Support aperiodic CSI report on PUCCH**

* Yes: Huawei [2], Futurewei [3], NTT DCM [23], vivo [4], ZTE [5], CATT [10], NEC [11], CMCC [17], Spreadtrum [18], Panasonic [20], InterDigital [15], Intel [12]
  + Trigger reporting based on traffic needs,
  + Less overhead than A-CSI on PUSCH in DL-dominant traffic
  + Report useful for retransmissions and subsequent TBs
* No: Samsung [16], Sony [8],
  + Small throughput gains as it does not benefit initial transmission
  + Latency too high for URLLC
  + Not useful in case of bursty interference
  + Retransmissions are rare
  + Specification impact, e.g. may require new field(s) in DCI
* Further study: Apple [21], Sharp [22], Lenovo [13]

The A-CSI on PUCCH has been discussed in the previous releases and it is observed that majority companies support the A-CSI on PUCCH. However, a few companies still have concerns on the benefits of the A-CSI on PUCCH for the URLLC scenario.

**Question #1:** considering that the A-CSI on PUCCH issue has been discussed and evaluated in the previous releases, can we make the decision to support the A-CSI on PUCCH based on the majority support?

* If no, what would be the suggested next step for this issue?

**Summary of the inputs:**

* Ready to make decision to support A-CSI on PUCCH (10):
  + Sony, FutureWei, InterDigital, DOCOMO, Spreadtrum, HW/HiSi, Panasonic, CMCC, CATT, ZTE
* Further study is needed (9):
  + Samsung, Nokia/NSB, Qualcomm, Intel, LG, Vivo, NEC, Lonovo, Sharp,
    - Several companies mentioned that performance evaluation is needed to identify technical merits based on common assumptions (scenarios, realistic assumption)

**Proposed conclusion:**

* Companies are encouraged to study and evaluate A-CSI on PUCCH scheme considering performance, specification impact, and signaling/RS overhead.

**Proposed conclusion:**

* Discuss on evaluation methodologies to be commonly used for the study and evaluation of CSI enhancement schemes proposed
  + Reuse the assumptions in TR 38.824 as baseline

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | We do not see the benefit but OK to consider given majority wants it. |
| Samsung | No | Decisions should be based on technical merits, not on a popularity contest.  Next step can be to identify technical merits under realistic assumptions and discuss/conclude on those assumptions. |
| Nokia/NSB | No | To our understanding, the Rel-17 discussion should be for CSI feedback enhancements to allow for more accurate MCS selection. This A-CSI on PUCCH was discussed during Rel-16 SI phase, but there was no sufficient gain to be included in the Rel-16 URLLC WI. Need better justification unless performance gains are showed compared to other proposals in this agenda item.  Also, we see that there are many other related problems arise with this solution vs compared to other solutions, and we have a limited time in the WI to finalize may be only one main direction due to that.  May be a good approach for now is that keep this just as one possible solution for further studies. |
| FUTUREWEI | Yes | A-CSI on PUCCH can be considered. |
| InterDigital | Yes | There were technical evaluations in R16 study that already showed gains at least for some URLLC scenarios. There are many possible use cases and scenarios for URLLC and certainly we cannot expect that the gain would be significant for all UEs in all scenarios. However, if the gain exists in relevant scenarios, supporting the enhancement can be justified.  If it is not acceptable to make a decision now then as a next step we can agree on the relevant scenarios and evaluate based on those. |
| Qualcomm | No | First, we would like to clarify that the discussions on all issues in Section 3 are only for A-CSI report on PUCCH measured using CSI-RS. Our response below is based on this understanding.  This topic was discussed in Rel-16 URLLC SI phase, and was not included in the Rel-16 WI because there’re not sufficient gains compared to other technologies. Better justifications and performance gains need to be identified before we can make a decision to support the proposal. Below we list our concerns on the issues with A-CSI report on PUCCH, which need to be addressed.   * Performance gain: as commented by Samsung, performance gains need to be identified compared to the baseline schemes (e.g., A-CSI on PUSCH or P-CSI on PUCCH) under realistic assumptions on the CSI-RS overhead, CSI estimation accuracy, interference condition, etc. * Downlink CSI-RS overhead vs CSI accuracy vs A-CSI report latency: One key question for the design is how frequently should CSI-RS reports and CSI-RS transmission be triggered? If the A-CSI report is to be triggered for every PDSCH transmission, then this incurs a very large CSI-RS/PUCCH overhead. On the other hand, if the A-CSI report is not triggered very frequently, then how should the base station determine whether or not to trigger a A-CSI report from the UE? * Significant spec impact: as commented by Nokia, there are many related problems that arise with this solution. Just to name a few: how to trigger the A-CSI report; how to indicate the CSI-RS resource, PUCCH resource; how to determine the timing of CSI-RS/PUCCH; how to solve collisions between A-CSI on PUCCH and other uplink channels (SRS, SR, P-CSI, SP-CSI on PUCCH, SP-CSI on PUSCH, A-CSI on PUSCH); CSI report content. Everything need to be sorted out in order to make the solution work.   UE implementation impact: related to the spec impact, the UE has to implement all aspects that are listed above. This will incur significant UE implementation complexity. |
| DOCOMO | Yes | Technical evaluations are presented in TR38.824 showing that A-CSI on PUCCH brings some gains for some URLLC scenarios. As InterDIgital mentions, there are various use cases for URLLC and thus, A-CSI on PUCCH will be beneficial for some of them. |
| Spreadtrum | Yes | We support this A-CSI on PUCCH enhancements.  In some heavy DL traffic scenarios, there is little chance for PUSCH transmission. However, CSI reports are essential for DL scheduling, especially URLLC traffic requires more instant A-CSI reports. Also evaluations in Rel-16 URLLC SI showed the gain of A-CSI on PUCCH in some scenarios. |
| HW/HiSi | Yes | As also described in the following sections A-CSI on PUCCH has advantages compared to traditional A-CSI, because it reduces the control overhead. Furthermore, it is very applicable for traffic scenarios that are typical for URLLC. |
| Panasonic | Yes | In Rel.16, aperiodic CSI is reported only PUSCH and triggered by UL DCI fo2rmat. However, if there is no UL data, using UL DCI format to trigger aperiodic CSI report in PUSCH without UL-SCH consumes PDCCH resource and too much resource for small amount of CSI report case. In addition, even if URLLC PUSCH is 1-symbol or 2-symbol, UCI and DMRS cannot be FDMed within a symbol for UCI multiplexing. Then, aperiodic CSI in PUSCH is not suitable for URLLC. |
| Intel | No | It has been shown by several sources, that link adaptation in URLLC/IIOT scenarios is limited by unpredictable interference. A-CSI on PUCCH does not solve this problem.  Furthermore, A-CSI on PUCCH triggered by DL assignment mainly target optimization of MCS for retransmissions, that could not bring much system gain overall in URLLC scenarios.  As a medium priority we can consider GC-DCI for CSI trigger as a new approach to trigger CSI reports with low overhead. |
| vivo | FFS | We are open to discuss.  Before making the decision, whether and how to reduce the CSI computation time should be discussed first, since it is important to harvest theㅂ benefits for A-CSI report on PUCCH.  On the merits of A-CSI on PUCCH, we think performance evaluation is needed to identify how much gain can be achieved. In order for that, evaluation methodology and assumptions need to be discussed first. |
| CMCC | Yes | For DL dominant URLLC traffic(e.g. motion control in factory automation), trigger A-CSI report by DL grant could save PDCCH overhead and benefit link adaptation. |
| NEC |  | We support A-CSI on PUCCH and agree with other supporting companies that technical evaluations in Rel-6 SI showed gains of A-CSI on PUCCH for some scenarios. However, we also agree that the decision should be based on technical merits and we are OK to first agree on the relevant scenarios and realistic assumptions and then discuss/conclude based on technical merits as compared to other proposals. |
| CATT | Yes | A-CSI on PUCCH is beneficial for subsequent scheduling. |
| Lenovo, Motorola Mobility |  | As mentioned above, A-CSI trigger by DL-DCI may be beneficial for reducing PDCCH blocking (especially in DL heavy traffic scenario), however, it is not clear to us if it leads to more accurate MCS selection compared to using existing A-CSI triggering via UL-DCI as the goal of the WID. |
| LG | No | We think aperiodic CSI is not suitable considering URLLC traffic characteristic (e.g., low packet size and sporadic). Though, given majority of companies’ view, we are Ok to discuss that. |
| ZTE | Yes | A-CSI on PUCCH should be supported for Rel.17 URLLC. |
| Sharp | FFS | We are open to discuss. However, the benefit to introduce A-CSI on PUCCH in terms of accurate MCS selection should be justified before making the decision. |
| MediaTek | No | Agree with Samsung’s comments |
| Ericsson | Yes | We are fine to have DL DCI triggered A-CSI. However, this is not a high priority item, when compared to other CSI enhancements, for the purpose of supporting URLLC/IIoT. For example,   * There exists A-CSI on PUSCH already. DL DCI triggered A-CSI is just an alternative; * In order to have DCI triggered A-CSI, CSI computation time should be reduced first, so that CSI and HARQ-ACK can be reported by the UE at the same time. |

### Issue #1-2

**Issue #1-2: Triggering method of aperiodic CSI report on PUCCH**

* Option-1: A-CSI is triggered by DL scheduling DCI
  + Yes: Huawei [2], NTT DCM [23], vivo [4], ZTE [5], CATT [10], NEC [11], CMCC [17], Spreadtrum [18], Panasonic [20], InterDigital [15]
    - Less overhead than UL-DCI in DL-dominant traffic
  + No: Samsung [16], Intel [12], Sony [8]
    - Specification impact, e.g. may require new field(s) in DCI
  + Further study: Apple [21], Sharp [22], Lenovo [13]
* Option-2: A-CSI is triggered by group-common DCI
  + Yes: Intel [12]
    - Less DL signaling overhead
  + No: Huawei [2], ZTE [5], NTT DCM [23], CATT [10]
    - Packet arrival time varies between UEs
    - Increase of blind decoding
  + Further study: Sony [8]
    - Consider overhead cost
* Option-3: A-CSI is triggered by NACK (without DCI)
  + Yes: ZTE [5]
    - May be useful for SPS PDSCH and sporadic traffic
  + No: Sony [8]
    - Not much benefit over soft combining (different RV’s)

The most of companies supporting A-CSI on PUCCH seems to also support DL DCI based triggering as it can avoid unnecessary PDCCH overhead in DL-dominant traffic cases.

**Question #2:** based on the majority support, can we at least agree on that DL DCI based triggering is used for A-CSI on PUCCH if the A-CSI on PUCCH is supported?

**Summary of the inputs:**

* Down-select to support DL DCI based triggering for A-CSI on PUCCH if supported (9):
  + FutureWei, InterDigital, DOCOMO, Spreadtrum, HW/HiSi, Panasonic, NEC, CATT, ZTE
* No down-selection of the options (10):
  + Support other options or open to discuss other options:
    - Sony, Intel, CMCC
  + Technical justification is needed (e.g., wait until Issue #1-1 is resolved):
    - Samsung, Nokia/NSB, Qualcomm, Apple, vivo, LG, Sharp

**Proposed agreement:**

* The following triggering options are considered for the study/evaluation of A-CSI on PUCCH:
  + Option-1: DL DCI
  + Option-2: group-common DCI
  + Option-3: NACK of a PDSCH (without DCI triggering)

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| **Company** | **Yes/No** | **Comments** |
| Sony | No | It isn’t useful for 1st PDSCH transmission. If we really want it for the retransmission (which is supposed to be rare in URLLC), then can consider Option 3. |
| Samsung | No | Majority support should not be the reason for an agreement. |
| Nokia/NSB | No | The question 2 heavily dependent on answer to question 1. Agree also with Samsung. |
| FUTUREWEI | Yes | Agree that DL DCI based triggering is used for A-CSI on PUCCH. We are also open to Option 3 where A-CSI is triggered by NACK. |
| InterDigital | Yes | There seems to be very little support for other options and the technical concerns for those are justified. |
| Qualcomm | No | We think the discussion can be deferred after evaluation results on Question #1 are provided/concluded. |
| Apple |  | Qualcomm raised a good point on evaluation. It would be good to have evaluation based design – not only for this particular issue. |
| DOCOMO | Yes | Agree that DL DCI based triggering. Also, we are open to discuss NACK based triggering. |
| Spreadtrum | Yes | It is easy to reuse these DL grant DCI to trigger A-CSI reports and select a PUCCH resource for them.  UE-specific DCI is more preferred compared with UE-group-specific DCI. UE-group DCI is designed for a group of UEs. Regarding A-CSI reports, they are per-UE requirements more than a group of UEs. Additionally, it needs a new DCI format defined for A-CSI reports on PUCCH. And a new RNTI should be introduced for this new DCI format. Obviously, this new DCI format will complicate UE implementation of PDCCH monitoring and also create some new problems of DCI size budgets. |
| HW/HiSi | Yes | In our view A-CSI in DL DCI is an elegant method, since no extra DCI overhead is needed.  For A-CSI in group common it is questionable how applicable it is, since the traffic patterns from various UEs might not be aligned.  Regarding Option 3, that is also a choice that could be considered in addition to option 1. For spectrum efficiency, it is also benfifical to have access to freash CSI reports in case of ACK, which then can be applied on the following TBs (for e.g. in ITS use cases, where larger packets on high layer result into multiple consecutive TBs in PHY) |
| Panasonic | Yes | Same reason in Question #1. |
| Intel | No | See our previous reply |
| vivo |  | It depends on the conclusion of Question #1. |
| CMCC |  | Agree option 1. Also, we are open to discuss option 2 and option 3. |
| NEC | Yes | If A-CSI on PUCCH is supported, A-CSI triggered by DL DCI can be supported. |
| CATT | Yes | We support DL DCI based triggering since it is simple and efficient, a DL DCI that is scheduling a PDSCH can be used to trigger the A-CSI. |
| LG | No | It would be discussed after resolving of Question #1 |
| ZTE | Yes | At least DL DCI based triggering should be supported.  NACK triggering is also effective for some use case. So we support to consider: Option-1, Option-3, and Option-1combined with Option-3. |
| Sharp | No | Conclusion on Question #1 should be made first. |
| MediaTek | No |  |
| Ericsson | Yes | We are fine to have DL DCI triggered A-CSI. However, this is not a high priority item as explained under Issue #1-1. |

### Issue #1-3 and #1-4

**Issue #1-3: Additional conditions for A-CSI reporting on PUCCH triggered by DL DCI**

* Option-1: New field in DCI
  + NTT DCM [23]
* Option-2: PDSCH is NACK
  + Huawei [2], ZTE [5]
* Option-3: DL DCI with high priority index
  + InterDigital [15], ZTE [5]
* Option-4: Activation by MAC CE
  + InterDigital [15]

Note: one or more of abovementioned options can be used together

Several contributions discussed details on how to trigger A-CSI on PUCCH actually, which include explicit indication in DL DCI and implicit trigger based on PDSCH decoding status or priority indicator in the associated DL DCI in order to reduce the DL and/or UL signaling overhead.

**Issue #1-4: PUCCH resource determination for A-CSI on PUCCH**

* Option-1 : RRC
  + Panasonic [20]
* Option-2 : MAC CE
  + InterDigital [15]
* Option-3: Same as HARQ-ACK
  + OPPO [14], Spreadtrum [18] (under conditions), Panasonic [20], NTT DCM [23]
* Option-4: DCI field (e.g. PRI)
  + NTT DCM [23], Panasonic [20], ZTE [5]
* Option-5: CSI request field
  + Panasonic [20]

Note: gray highlight here means that a company mentioned the proposal in the tdoc but not clearly indicate whether the company supports it or not

Several contributions discussed the options related to the PUCCH resource determination when A-CSI on PUCCH is supported. Similar to the Issue #1-3, this issue is also the next level of details which can be discussed after the support of A-CSI on PUCCH is agreed.

**Question #3:** regarding Issue #1-3 and Issue #1-4, these issues are a next level of details to be discussed if A-CSI on PUCCH is agreed. Do we need to put this issue on hold until the A-CSI on PUCCH is agreed?

* In the meantime, please provide any additional options if you have

**Summary of the inputs:**

* Issues #1-3 and #1-4 should be discussed if/after RAN1 agrees to support A-CSI on PUCCH (18):
  + Sony, Samsung, Nokia/NSB, FutureWei, InterDigital, Qualcomm, Apple, DOCOMO, Spreadtrum, Panasonic, Intel, vivo, CMCC, NEC, CATT, LG, ZTE, Sharp
* Issues #1-3 and #1-4 can be discussed in parallel with A-CSI on PUCCH:
  + HW/HiSi

**Proposed conclusion:**

* Additional conditions for A-CSI reporting on PUCCH and PUCCH resource determination for A-CSI on PUCCH to be discussed if/when RAN1 agrees to support A-CSI on PUCCH:

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony |  | Consider the details after agreeing whether to support or not support this feature. |
| Samsung | Yes | For the reasons mentioned in “Question #3” |
| Nokia/NSB |  | These issues can be revisited once the basic direction of the solution is identified. |
| FUTUREWEI | Yes | Agreed that the next level of details can be discussed after Questions #1 and #2 have been resolved. |
| InterDigital | Yes |  |
| Qualcomm | Yes | As commented under “Question #2”, these issues can be discussed/revisited once a decision on Question #1 is made. |
| Apple | Yes | Yes, while we are open to all studies/proposals, we can wait for better clarity to treat such issues |
| DOCOMO | Yes |  |
| Spreadtrum | Yes | We are open to this issue. |
| HW/HiSi | No | We think it would be good to progress also on issues 1-3 and 1-4 in parallel. At least companies can exchange and align their views, so that progress can be quicker once the A-CSI on PUCCH is supported.  For issue 1-3: In addition to NACK triggered A-CSI (Option 2), we also think it would be good to include Option 1 and Option 3.  For issue 1-4: we think a maybe more important question that will set to direction for further work is whether HARQ-A/N and CSI report are on the same resource or on different resources (or if both should be allowed) Both approaches have their pro’s and cons’s. Then, after that we could maybe list candidate methods for separate and for joint reporting and shortly characterize them? |
| Panasonic | Yes | These issues should be discussed after agreeing whether to support A-CSI on PUCCH and/or A-CSI reporting on PUCCH triggered by DL DCI. |
| Intel | Yes | Need to first decide on the direction itself |
| vivo |  | It depends on the conclusion of Question #1. |
| CMCC | Yes |  |
| NEC | Yes |  |
| CATT | Yes |  |
| LG | Yes | It would be discussed after resolving of Question #1 |
| ZTE | Yes | This question is also related to the CSI processing latency. If the CSI processing latency can align with the HARQ-ACK processing latency, Option-3 is recommended. Otherwise, Option-1+Option-4 is recommended. |
| Sharp | Yes |  |
| MediaTek | Yes |  |
| Ericsson | Yes | This issue should wait until the A-CSI on PUCCH is agreed |

## Reduction of CSI computation time

**Background**

The minimum CSI computation time is larger than PDSCH processing time (e.g., PDSCH processing capability 2) in current specification. Therefore, even if A-CSI reporting is triggered in the symbol where a PDSCH is scheduled, a UE may report A-CSI later than the associated HARQ feedback (or HARQ feedback is delayed to be reported together with A-CSI) which may result in delayed retransmission scheduling.

### Issue #1-5

**Issue #1-5: Reduction of CSI computation time**

* Yes: FutureWei [3], Ericsson [6], vivo [4], CATT [10], Lenovo [13], OPPO [14], CMCC [17], propose to study how to support reduction of CSI computation time
  + To improve accuracy/timeliness of CSI report for URLLC
  + To allow reporting of CSI at the same time as earliest possible transmission of HARQ-ACK or PUSCH based on PDSCH processing capability 2 (N1/N2)
  + Proposals to ease CSI computation:
    - Simplified CSI report: CATT [10], Lenovo [13]
    - Partial report: Ericsson [6], Vivo [4], OPPO [14], Lenovo [13]
    - Simplified measurement from data reception status: OPPO [14]
    - Only report sub-band CQI: CMCC [17]
    - More capable UE: Ericsson [6], Futurewei [3]
    - Reporting CQI’s for more than one table in a report: Intel [12]

**Observations**

The minimum required CSI computation time has been specified in section 5.4 of 38.214. Several companies observed that for a UE with PDSCH (PUSCH) processing capability 2, timeline requirement allows for reporting of HARQ-ACK (or transmission of PUSCH) earlier than for reporting A-CSI triggered from same DCI.

**Question #4:** should CSI computation time reduction be supported for faster CSI reporting in Rel-17?

* If yes, any additional restriction is required to reduce the computation time?

**Summary of the inputs:**

* Yes (11), reducing CSI processing time would be beneficial or open to discuss:
  + Futurewei, InterDigital, DOCOMO, Panasonic, vivo, CMCC, NEC, CATT, Lenovo, LG, Sharp
* No (8),
  + Not beneficial: Sony, Nokia, Apple, Intel
  + Not feasible: Samsung, Qualcomm, Spreadtrum
  + Not critical: ZTE
* FFS:
  + HW/HiSi

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | No | This issue is created due to DL Grant triggered A-CSI, which we do not think is beneficial for URLLC purpose. |
| Samsung | No | This is difficult for UE implementation – no meaningful reductions are possible. |
| Nokia/NSB | No | First, we should investigate the performance impact or gains compared to the increase in complexity at the UE side. In our investigations, considering the case of increasing the CQI reporting frequency or reducing the ‘CQI processing delay’ does not make a huge difference to URLLC performance, since the channel (especially intereference) coherence time is extremely small. |
| FUTUREWEI | Yes | CSI computation time reduction could enable faster CSI feedback. It can be defined as optional UE capability and optional network feature in Rel-17 to better support URLLC. |
| InterDigital | Yes | This is useful when the signal part of the CSI has coherence time of the order of slot. It is true that the gain is less if the interference varies a lot, but it should be noted that not all UEs experience such conditions, e.g. UEs close to cell center may not experience big interference variations. |
| Qualcomm | No | First, we would like to clarify that the discussions on all issues related to the CSI computation time in Section 3.2 are only for A-CSI report measured using CSI-RS. Our response below is based on this understanding.  UE CSI computation time has been extensively discussed and optimized during NR Rel-15. In particular the CSI computation delay requirement 1 in NR Rel-15 is defined for a very restricted/simplistic scenario in which only wideband CQI corresponding to up to 4 CSI-RS port in a single CSI resource without CRI report is requested and only single-panel codebook is configured. Further reducing the computation timeline is very difficult for UE implementation, and we don’t see a meaningful way to achieve this. |
| Apple | No | If the main reason for CSI fluctuation is interference (both intra-cell and inter-cell interference), then the root cause for that is the NR design itself and small time units enabled for scheduling. Faster CSI feedback is supposed to lead to faster scheduling decision which leads to even-faster changes in interference a UE experiences, feeding such a vicious cycle really does not help. We don’t see the point of tightening CSI processing time. |
| DOCOMO | Yes | We are open to discuss this. In our understanding, this issue is not only related to A-CSI triggered by DL grant but also for the existing A-CSI on PUSCH. The proposed scheme like partial reporting could help to reduce the computation time. |
| Spreadtrum | No | The definition of CSI computation time had taken the factors in to account thus two types of processing time are given. From our understanding, this faster CSI computation of enhancement to URLLC is unclear, and it will significantly increase the complexity of UE implementation. |
| HW/HiSi |  | We cannot really answer this question with yes/no at this stage. And we think that RAN1 should look further into this. If faster CSI processing can be achieved with reasonable UE complexity, then this is of course desirable.  In such case, restrictions would be needed and the contents of the CSI report should be discussed. As mentioned by multiple companies, the dominant component that is contributing to quick channel state changes is the interference. So this one direction to look into.  But we think firstly, we should agree on the tool to carry the CSI report, i.e. A-CSI on PUCCH, and then discuss the details what to be included in the report |
| Panasonic | Yes | To reduce the CSI computation time would be beneficial if A-CSI reporting on PUCCH is supported. |
| Intel | No/not yet | We also observe that reduced CSI computation time on its own does not combat the main limiting factor of link adaptation – unpredictable interference.  However, we are open to revise the numbers once new procedures are introduced in this WI |
| vivo | Yes | Reducing the CSI computation time is necessary for timely CSI acquisition for URLLC. And it is important to harvest the benefits for A-CSI report on PUCCH. Whether and how to reduce the CSI computation time should be discussed in high priority. |
| CMCC | Yes | In our view, CSI computation time can be reduced by UE implementation or optimization of CSI report quantity. The later one may be more reasonable. |
| NEC | Yes | We are open to discuss the proposals which can enable faster CSI computation. |
| CATT | Yes | CSI computation time reduction would benefit A-CSI on PUCCH. |
| Lenovo, Motorola Mobility | Yes | In our view, CSI computation time reduction is the most straight-forward way of getting fresh MCS. We are open to discuss different ways of achieving CSI computation reduction (e.g., more capable UE, simplified CSI report, partial report, etc.) |
| LG | Maybe | It could be beneficial to support reduced CSI processing time but it would be optional in terms of UE capabilities. |
| ZTE | No | CSI computation time has been studied long time, it is not critical to discuss the reduction of time. |
| Sharp | Yes | Reflecting up-to-date channel state would be a key in terms of accurate MCS selection. |
| MediaTek | Maybe |  |
| Ericsson | Yes | Long CSI computation delay is a major problem since Rel-15. We are open to discuss exactly how to assist UE so that reduction can be achieved. |

**Question #5:** Is CSI computation time reduction issue tied with A-CSI on PUCCH?

* If yes, should we put this issue on hold until the decision is made for A-CSI on PUCCH?
* If no, in which case the CSI computation time reduction can provide gain?

**Summary of the inputs:**

* Yes, it is dependent on the outcome of A-CSI on PUCCH (4)
  + FutureWei, InterDigital, Panasonic, CATT
* No, it is not dependent on the outcome of A-CSI on PUCCH (12)
  + Samsung, Nokia, Qualcomm, Apple, DOCOMO, Spreadtrum, HW/HiSi, Vivo, CMCC, NEC, LG, Sharp

**Suggestion for discussion:**

* Study further on CSI processing time reduction of A-CSI reporting in terms of technical benefit and feasibility for both PUCCH and PUSCH

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Agree to consider this after decision is made for A-CSI on PUCCH. |
| Samsung | No | There is only a lower level relevance. |
| Nokia | No | We assume that the FL refer to the A-CSI computation time. We would be happy if the UE can reduce the computation times, but it looks to us that this kind of seperate investigations are not within WI objective. |
| FUTUREWEI | Yes | Agree that this issue can be discussed after decision is made for A-CSI on PUCCH. |
| InterDigital | Yes | If A-CSI on PUCCH is not supported, the relevance of reducing CSI computation time is unclear. |
| Qualcomm | No | As commented above, CSI computation time has been heavily optimized in NR Rel-15 and 16, and it is very difficult for UE implementation to further reduce it, regardless of whether CSI report is conveyed over a PUCCH or a PUSCH. |
| Apple | No | See our reply above |
| DOCOMO | No | Same as our input for Question #4. CSI computation time reduction can be considered for A-CSI on PUSCH as well. |
| Spreadtrum | No | We prefer not to treat it in Rel-17. |
| HW/HiSi | No | Reduced CSI computation time should not be pre-requisite for A-CSI on PUCCH.  A-CSI on PUCCH can have significant gain compared to tradition A-CSI due to reduced control overhead. We have evaluated the performance difference between A-CSI on PUCCH and traditional A-CSI in R1-1903190) for the Rel-15 enabled use case and observed gain of 37%.  In addition, some URLLC use case have bursty data traffic and less strict latency requirements (example power grid). Also for such use cases, A-CSI is beneficial and the UE processing time capability #1 is sufficient to even apply the CSI report on the retransmission.  Another use case that benefits from A-CSI in general is ITS (remote driving). Here, one large packet on higher layer is broken down into several TBs that are transmitted consecutively in bursts. Even with the current CSI processing time, the CSI report can be used for the following transport blocks. |
| Panasonic | Yes | This issue could be discussed after agreeing whether to support A-CSI reporting on PUCCH triggered by DL DCI. |
| Intel |  | We observe that many proponents of reduced CSI computation time assume that this CSI is triggered by DL assignment DCI, thus we see correlation.  However, we are not ready to prioritize A-CSI on PUCCH and associated discussions on computation time. |
| vivo | No | If CSI computation time can be reduced, it would be beneficial for URLLC to obtain A-CSI report on PUSCH or PUCCH (if supported). |
| CMCC | No | CSI computation time reduction can also be considered for A-CSI on PUSCH. |
| NEC | No | CSI computation time reduction can also be considered for A-CSI on PUSCH. |
| CATT | Yes |  |
| Lenovo, Motorola Mobility |  | Actually, we favour the opposite direction: we should put A-CSI on PUCCH on hold until the decision is made for CSI computation reduction (although in general we don’t see the benefit of A-CSI on PUCCH for more accurate MCS selection compared to the existing schemes, see our comments above), because the specification of A-CSI on PUCCH can be very dependent on the CSI computation time (e.g., whether to use the same PUCCH resource for HARQ-ACK and CSI, especially for PDSCH processing capability 2). |
| LG | No | If the reference signal for CSI measurement is not different in the case of A-CSI of PUCCH, there is no reason to defer the discussion. Reduced CSI processing time can be applied to any CSI transmission like A-CSI on PUSCH. |
| Sharp | No | CSI computation time reduction can also be considered for A-CSI on PUSCH. |
| MediaTek | No |  |
| Ericsson | No | CSI computation delay reduction can benefit any A-CSI report such that CSI report provides timely channel condition info to gNB. |

## Priority of P/SP-CSI/[A-CSI] on PUCCH

**Background**

The P/SP-CSI on PUCCH has been considered as a lowest priority as compared with other CSI reporting types and no priority index associated with the CSI reporting configuration. Therefore, even if it is targeted for URLLC traffic link adaptation, it may be dropped if it collides with a higher priority CSI reporting (e.g., A-CSI reporting, SP-CSI on PUSCH) irrespective of whether the higher priority CSI reporting is targeted for eMBB or URLLC.

### Issue #1-6

**Issue #1-6: Priority applicable to P/SP-CSI on PUCCH and (if supported) A-CSI on PUCCH**

* Mediatek [9], Samsung [16], Intel [12], propose that P/SP-CSI on PUCCH can have priority index 1 in some cases
  + Proposals for assignment of priority:
    - BLER target of the configured CQI table: Mediatek [9]
    - Semi-static configuration or activation: Intel [12]
* NTT DCM [23] and Panasonic [20] propose that A-CSI on PUCCH (if supported) can have priority index configurable, e.g. indicated from DCI
* NTT DCM [23] also proposes that priority used in clause 5.2.5 in 38.214 for A-CSI PUCCH is higher than for A-CSI on PUSCH
* FutureWei [3] proposes CSI reporting procedures with less CSI report dropping due to collision

**Observations**

Several companies propose to introduce an additional means to support priority configuration or determination of P/SP-CSI on PUCCH as well as A-CSI on PUCCH (if supported) so that dropping of those CSI reporting due to collision with a high priority CSI reporting targeting eMBB.

**Question #6:** Should possibility of configuring priority index 1 at least for P/SP-CSI be supported in R17?

* If A-CSI on PUCCH is supported, should it be possible to configure it with priority index 1

**Summary of the inputs:**

* Yes (10)
  + Samsung, InterDigital, DOCOMO, Spreadtrum, Intel, NEC, Lenovo, ZTE (only for A-CSI on PUCCH), Qualcomm, Huawei (at least for A-CSI on PUCCH)
* No (6)
  + Sony, Nokia, FutureWei, vivo, CATT, LG
* FFS (3)
  + Sharp, Apple, CMCC

**Suggestion for discussion:**

* Study further on configuring priority index 1 for P/SP-CSI and A-CSI on PUCCH (if supported) in terms of the technical benefit and specification impacts

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | No | CSI is not so critical for latency purpose as the gNB can still schedule the UE without the latest CSI report. However, if we attach a high priority to CSI and it collides with a LP PUSCH, the LP PUSCH is dropped, which is an overkill. Whereas in Rel-16, the CSI can be multiplexed into the LP PUSCH thereby transmitting both to the gNB, which is a better outcome. |
| Samsung | Yes | Because separate report is needed for URLLC (e.g. low MCS table) and can be often dropped either due to collisions or due to resource availability when multiplexed with HARQ-ACK. Spec impact is practically zero. |
| Nokia/NSB | No | We do not see the necessity of having high priority index 1 for P/SP-CSI even for URLLC traffic as already agreed in Rel-16. |
| FUTUREWEI | No | Consider defining additional CSI transmission opportunity in PUCCH or PUSCH to reduce CSI report dropping due to collision. |
| InterDigital | Yes | This could be useful for example if the URLLC traffic is periodic and the network wants to get a fresh CSI just before a traffic burst. |
| Qualcomm |  | Medium priority. We think that there are technical metrics on supporting high priority P/SP-CSI to give gNB more accurate information about the channel condition for URLLC. |
| Apple |  | It can be discussed along with other proposals. |
| DOCOMO | Yes | Share the same view as InterDigital. This would be useful for periodic URLLC traffic. |
| Spreadtrum | Yes | Since P/SP CSI reports are always low priority in Rel-16, it may drop P/SP CSI when collision with HP HARQ-ACK or SR. However, P/SP CSI with high priority would be essential due to DL/UL URLLC scheduling. |
| HW/HiSI |  | For A-CSI on PUCCH it is definitely desirable to support priority 1. The details mechanism could be decided, it could follow the priority of the scheduling DCI.  For P/SP-CSI, it can also be helpful to configure priority index 1 for deterministic URLLC traffic that is multiplexed with eMBB but it also could be solved by other means.  Low priority. |
| Intel | Yes | We think R16 decisions on always low priority for P/SP-CSI on PUCCH were motivated by no objective to enhance CSI accuracy.  This time, this assumption can be reconsidered. It may be as important as to improve the CSI measurements overall, since there may be no value in a sophisticated report suddenly dropped due to low priority. |
| vivo | No | We are not sure the necessity for P/SP-CSI of high priority, given that gNB can trigger A-CSI of high priority for URLLC. |
| CMCC |  | Medium priority. We are not sure how much gains it can provide. |
| NEC | Yes | Possibility to configure priority index 1 for CSI report can be useful for URLLC. The mechanism can be FFS. |
| CATT | No |  |
| Lenovo, Motorola Mobility | Yes | makes sense to us for collision handling |
| LG | No | We have similar view to Nokia. |
| ZTE | For P/SP-CSI, No.  For A-CSI on PUCCH, Yes. | We agree with NTT DCM [23] and Panasonic [20].  For P/SP-CSI on PUCCH, only priority index 0 is enough. For Rel.17 URLLC, link adaption with P/SP-CSI on PUCCH is inefficient, so P/SP-CSI on PUCCH enhancement has very low priority.  For A-CSI on PUCCH, priority index 0 or priority index 1 can be indicated from DCI. |
| Sharp |  | We are open to discuss. Some gain would be expected, but this may not solve everything. |
| MediaTek | No |  |
| Ericsson |  | No for P/SP-CSI  Yes for A-CSI on PUCCH, if A-CSI on PUCCH is introduced in Rel-17 |

# Enhancements for more accurate CSI reporting

## Enhancements for bursty interference conditions

**Background**

Several companies identified the following issues on the existing CSI report types for URLLC scheduling especially under bursty interference environment

* Channel/interference measurement resource configuration is not flexible enough
* Channel and interference should be measured at the same time always although only interference part is changed dynamically
* Wideband CQI is not accurate when a small number of RBs are scheduled
* Channel prediction is not accurate at the scheduler with existing CSI

### Issue #2-1

**Issue #2-1: introduce new CSI report type(s)**

* Yes: Futurewei [3], Ericsson [6], Nokia [7], Intel [12] propose enhancements to provide additional or more relevant information to help scheduler select MCS for reliable transmission when interference is bursty
  + Proposals
    - Separate CSI reporting of signal information and interference information: Futurewei [3]
    - Report interference statistics (e.g. minimum, maximum, stddev): Futurewei [3]
    - Report CQI or SINR statistics (e.g. variance): Ericsson [6], Nokia [7]
    - Explicit interference averaging: Intel [12]
    - Filtered CSI reporting (e.g. report only when CQI changes): Intel [12]
    - Report the CQI associated with the worst-M sub-bands: Nokia [7]

**Observation**

The necessity of a new CSI report type for better capturing interference characteristics is seen by several companies but the proposals are diverging at this point and more details are needed.

**Question #7:** Should new CSI report type(s) be supported to better capture interference characteristics in URLLC scenarios?

* If yes, do we need to agree on common scenario, assumptions and metrics for comparing the different schemes?

**Summary of the inputs:**

* Yes (9): Sony, Nokia/NSB, FutureWei, InterDigital, DOCOMO, HW/HiSi, Intel, CMCC, Shrap
  + Interference statistics: Sony, FutureWei, DOCOMO
  + Not limited to interference statistics: CMCC
* No (5): Samsung, Qualcomm, vivo, LG, ZTE
  + Not useful: Samsung, LG
  + Need technical justification: Qualcomm, vivo, ZTE
* FFS (2):
  + Spreadtrum, Panasonic

**Proposed conclusion:**

* Companies are encouraged to study and evaluate new CSI report type(s) in terms of technical benefit and specification impacts.
  + For performance evaluation, each proponent needs to provide detailed assumption of the proposed new CSI report type(s), including
    - reporting values
    - measurement resource
    - how to use the reported new CSI report type(s) at the gNB scheduler

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | More information especially on the characteristic of the intereference is useful for accurate MCS selection at the gNB. |
| Samsung | No | Robustness is key in URLLC. Short-term/instantaneous statistics cannot be relied upon for future scheduling. There is also always the issue with accuracy of measurements, quantizations, and reliable, practically error-free, feedback, dependence on transmission scheme, diversity scheme, .... |
| Nokia/NSB | Yes | As we see from our evalutions, we see certain gains with such approaches. It is convenient to have an agreed/unified way forward for comparing the performance of the different proposals. |
| FUTUREWEI | Yes | Report of interference statistic such as standard deviation, max, and min, etc., allows for more accurate MCS selection at the gNB. The interference statistics need not be short term. Detailed format of reporting can be FFS. |
| InterDigital | Yes | For UEs subject to fast interference variations such enhancements are helpful for the network. We need to agree on common assumptions to compare different candidates. |
| Qualcomm | No | URLLC system should be designed to be robust against very rare event. It is unclear to us whether/how statistical CSI information could help increasing the reliability, and if so to what percentile the statistics need to be reported/measured.  For example, it is unclear how an 80% percentile CSI report or the variance of the CSI report could be helpful to achieve a 1e-5 BLER target. Need more evaluation results to justify the proposal. |
| DOCOMO | Yes | Reporting of statistics information could help gNB to select accurate MCS. |
| Spreadtrum |  | We are open for this issue. |
| HW/HiSi | Yes | Firstly, we should agree on the tool to carry the CSI report, then we should discuss this issue here. As many companies have pointed out, this is an area that has potential to improve the performance. |
| Panasonic | FFS | Need to have evaluation first and identify potential benefits. |
| Intel | Yes | We consider this as the main objective of this WI, since all other optimization do not directly solve the issue of MCS setting accuracy. |
| vivo | No | The necessity to introduce new CSI report types needs to be further clarified.  In order to identify the potential gain from introduction of new CSI report types, performance evaluation is needed. The evaluation methodology and assumptions should be discussed first. |
| CMCC | Yes | We agree to discuss new CSI report type(s), but we prefer not to limit the scope only to better capture interference characteristics. |
| NEC | YEs | Common scenario, assumptions and metrics need to be agreed to compare different schemes. We agree with CMCC not to limit the scope to better capture interference characteristics. |
| CATT | FFS | Further study and evaluations are needed. |
| Lenovo, Motorola Mobility |  | This topic is quite interesting and can be discussed in a more general framework than URLLC. |
| LG | No | In order to meet least reliability requirement, such fuzzy calculation of CSI would be not helpful. It seem to be considered to enhance reliability in average sense only but the problem of URLLC comes from 5%-tile UE in most of case. |
| ZTE | No | Evaluation results should be provided to prove the new CSI content is beneficial for at least one common URLLC scenario. |
| Sharp | Yes | New CSI report type can be considered to adjust a balance between CSI acquisition time and MCS selection accuracy. |
| MediaTek | Yes | This is something that worth study and evaluating. |
| Ericsson | Yes | CQI report provides averaged information about channel/interference (basically mean), while actual SINR may vary quite a lot. It can be observed that in quite many scenarios actual SINR distribution can be approximated by normal or skewed normal distribution. By knowing certain variance/percentile and mean, SINR distribution can be approximated at gNB and optimal (from latency and efficiency point of view) LA backoff can be chosen.  We are open to discuss common scenario for evaluations, however, it is not strictly needed, and may require a long time to converge. |

## More accurate sub-band CQI feedback

**Background**

A few companies raised concern on the accuracy of the current subband CQI as 2-bit delta CQI used with quantization and the quantization error is relatively large, resulting in inaccurate subband CQI.

### Issue #2-2

**Issue #2-2: Need for enhancing accuracy of sub-band differential CQI feedback**

* Yes: Huawei [2], Mediatek [9], CMCC [17] propose enhancements to improve accuracy of sub-band differential CQI feedback
  + Proposals
    - Sub-band CQI with no differential CQI (Huawei [2])
    - New differential CQI tables (Mediatek [9])

**Question #8:** Should performance of sub-band CQI reporting be enhanced for R17?

* If yes, do we need to agree on common scenario, assumptions and metrics for comparing the different schemes?

**Summary of the inputs:**

* Yes (5): Sony, FutureWei, HW/HiSi, CMCC, MediaTek
* No (6): Nokia/NSB, InterDigital, Qualcomm, DOCOMO, LG, ZTE
  + Consider it as an alternative to new CSI report type(s): Nokia/NSB, DOCOMO
  + Additional feedback overhead should be taken into account: ZTE
* FFS (8): Samsung, Spreadtrum, Intel, vivo, NEC, CATT, Lenovo, Sharp

**Proposal for Conclusion:**

* Discussion on enhancement of subband differential CQI feedback is deprioritized under IIoT/URLLC enhancement WI

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| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Can be further studied but not high priority. |
| Samsung | Maybe | Rel-15 provides the necessary tools for sub-band CSI reporting. New simpler reporting modes can be considered. But overlap with similar work in Rel-17 MIMO should be avoided. |
| Nokia/NSB | No | We prefer to have alternative CSI/CQI report types (e.g. as in Section 4.1) which can provide similar benefits with (much) lower uplink reporting overhead.  As a potential way forward, the decision between new CSI/CQI report types and/or enhanced sub-band reporting can be based on performance evaluation. |
| FUTUREWEI | Yes | Enhanced sub-band CQI reporting can be considered. |
| InterDigital | No | The relevance of this type of enhancement to URLLC is unclear. |
| Qualcomm | No | We don’t see the benefit for enhancing sub-band CQI reporting beyond Rel-15. |
| DOCOMO | No | Can be deprioritized since similar benefits might be obtained by new CSI type in section 4.1. |
| Spreadtrum |  | We prefer it is with the low priority. |
| HW/HiSi | Yes | The sub-band CQI is very suitable for the packets sizes in URLLC applications. But the granularity of the current mechanism is too coarse to allow for accurate CSI feedback. |
| Intel |  | We are open to this |
| vivo |  | The necessity to introduce more accurate sub-band CQI feedback needs to be further clarified. In addition, how much gain from the introduction of more accurate sub-band CQI feedback should be investigated first. |
| CMCC | Yes | We think it is beneficial for sub-band scheduled URLLC traffic. |
| NEC |  | Medium priority since similar benefits can be provided be new CSI report type(s). |
| CATT | FFS | Further study and evaluations are needed. |
| Lenovo, Motorola Mobility |  | In our view, first CSI computation time reduction should be discussed and then we can assess if such enhancement is relevant in that context. |
| LG | No | The benefit is unclear to us |
| ZTE | No | The tradeoff between the additional feedback overhead and performance gain should be considered, especially for the frequency domain configuration of multiple sub-bands case, the additional feedback overhead can’t be ignored. |
| Sharp | FFS | Further study and evaluations are needed. |
| MediaTek | Yes |  |
| Ericsson | Yes | We are open to discuss enhancement of sub-band reporting. Our main motivation is, sub-band reporting can be modified such that the UE can generate the CSI report faster. Currently, the CSI computation delay associated with subband reporting is one of the worst cases. |

# Other enhancements

## Enhancements to support OLLA with low BLER target

**Background**

An ACK/NACK based outer loop link adaptation has been used and it worked fine with eMBB use case since it has higher target BLER (). However, for URLLC, the ACK/NACK based OLLA performs poorly since NACK occurs very rarely as it targets much lower BLER () and it cannot track the channel/interference variation dynamically.

Also, the latency bound can be small with URLLC, the gNB and UE do not have the time to conduct multiple rounds of HARQ retransmission. Providing additional information to the gNB would allow it to allow enough resources for the UE to decode the transmitted packet within the latency bound.

### Issue #3-1

**Issue #3-1: Need for additional information bundled to HARQ-ACK**

* Yes: Ericsson [6], Oppo [14], ZTE [5], Nokia [7], Apple [26], Qualcomm [27] propose to bundle additional information to the HARQ-ACK report
  + Proposals
    - Decoding margin: Ericsson [6], ZTE [5]
    - Compressed CSI report: Oppo [14], ZTE [5]
    - Estimated error probability, e.g. LLR: Nokia [7], Oppo [14]
    - Recommended RV sequence: Apple [26]
    - PDSCH decoding failure reason: Qualcomm [24][27]
    - Per-TRP decoding result: Qualcomm [27]
    - Preferred beam, subband, and/or component carrier info: Qualcomm [27]
    - New Tx-Rx beam pair request: Qualcomm [24][27]
    - Instantaneous MCS/CQI feedback: Qualcomm [27]

Note: Apple [26], Qualcomm [27] contributions submitted under AI 8.3.1.1

**Observation**

OLLA performance issue is seen by several companies and those companies see the benefit of additional information bundled with HARQ feedback for better OLLA performance.

**Question #9:** Should R17 support reporting of additional information bundled to HARQ-ACK?

* If yes, what should the additional information be obtained from (e.g., PDSCH, CSI-RS, etc.)?

**Summary of the inputs:**

* Yes (9): Sony, Nokia/NSB, FutureWei, InterDigital, Qualcomm, Apple, DOCOMO, Spreadtrum, ZTE
* No:
* FFS (10): Samsung, Huawei, Panasonic, Intel, vivo, CATT, NEC, Lenovo, LG, Sharp

**Proposed conclusion:**

* Companies are encouraged to study and evaluate additional information to be bundled to HARQ feedback in terms of technical benefit and specification impacts. For performance evaluation:
  + each proponent provides detailed assumption of the proposed additional information to be bundled to HARQ feedback, including
    - how scheduler uses the additional information for retransmission and/or sub-sequent transmission

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | We can consider the details after decision is made on this feature. |
| Samsung | Maybe | Need to have evaluation first and identify potential benefits – cannot say ‘yes’ or ‘no’ to concepts. Several proposals fall under MIMO (and some are part of Rel-17 MIMO). The remaining do not seem necessary. |
| Nokia, NSB | Yes | For outer loop link adaptation, we see it convenient to derive the additional information from the PDSCH. |
| FUTUREWEI | Yes | These features can be considered but with low priority. |
| InterDigital | Yes | For outer loop link adaptation and based on PDSCH. |
| Qualcomm | Yes | Link adaptation scheme based on traditional Ack/Nack feedback perform quite poorly in the 1e-5 BLER regime, because it is not fast enough to track the instantaneous channel fading and interference with high accuracy. Additional information besides the traditional ack/nack can be very helpful for the gNB to make accurate scheduling decisions. The potential contents for the additional information are as listed by the FL above.  For example, in case of mTRP, UE can report PDSCH decoding result per TRP in addition to the final decoding result by combining the PDSCH repetitions from both TRPs. Based on the decoding result per TRP, gNB may quickly identify and replace a TRP of poor link quality with another TRP, e.g. when a TRP has X consecutive decoding failures.  As another example, fast and instantaneous MCS/CQI feedback based on the PDSCH decoding can help maintain the link adaptation to achieve URLLC BLER requirement with efficient RB use. Furthermore, deriving the additional information from the PDSCH is more convenient than from the CSI-RS: it does not require additional CSI-RS overhead, and can afford faster feedback compared to CSI feedback based on the CSI-RS. |
| Apple | Yes | URLLC brings unique challenges, we are open to proposals to address them. The latency bound can be small with URLLC, the gNB and UE do not have the time to conduct multiple rounds of HARQ retransmission. Providing additional information to the gNB would allow it to allow enough resources for the UE to decode the transmitted packet within the latency bound. |
| DOCOMO | Yes | Would be beneficial. Details should be considered after decision on whether to study this feature. |
| Spreadtrum | Yes | We are open to the suggestions. |
| HW/HiSi | Maybe | This could be studied with low priority at the stage. As mentioned by multiple companies, OLLA could need to be improved for URLLC target BLER. |
| Panasonic | FFS | Need to have evaluation first and identify potential benefits. |
| Intel | Maybe | Evaluation is required to see the benefits vs complexity/OH  Again, optimization of the resource allocation for retransmissions may not bring noticeable performance benefits since the initial transmission itself should be quite robust in URLLC scenarios |
| vivo |  | How much gain from the introduction of additional information bundled to HARQ-ACK should be investigated first. |
| NEC |  | This can be considered with low priority. |
| CATT | FFS | Further study and evaluations are needed. |
| Lenovo, Motorola Mobility |  | Although, these approaches are quite interesting, they are quite diverse, and some of them can be discussed under different topics (such as beam management). Also, timeline for such calculations/reports should be studied such that not affecting the HARQ-ACK timeline. |
| LG | Maybe | Up to proposals. We are open to discuss further. |
| ZTE | Yes | The additional information can be obtained from PDSCH (excluding DMRS), such as some information from PDSCH decoding, the feedback latency is better than measurement from CSI-RS. |
| Sharp |  | This can be studied, as legacy OLLA does not work well with URLLC target BLER. |
| MediaTek | Maybe | Can be considered for study |
| Ericsson | Yes | Provide OLLA with decoding margin information. This margin info is readily available from PDSCH decoding, and this info require little overhead (e.g., 1 bit added to existing HARQ-ACK report). |

## Enhancements for URLLC in multi-TRP scenarios

**Background**

From Rel-16, the multi-TPR transmission (NCJT) has been supported but there is no CSI feedback design optimized for the multi-TRP transmission

### Issue #3-2

**Issue #3-2: Enhanced CSI reporting for multi-TRP scenarios**

* Yes: Futurewei [3], Ericsson [6], propose CSI enhancements optimized for multi-TRP transmission schemes with high reliability
  + Proposals
    - Joint CSI report for multi-TRP URLLC scenario: Ericsson [6]
    - UE selecting whether a RS resource is for CM, IM, or muting: Futurewei [3]

The support of tailored CSI feedback design for multi-TRP transmission is proposed by two companies. Considering that multi-TRP enhancement is currently under Rel-17 FeMIMO WI, it is unclear whether this issue should be studied in the URLLC/IIoT WI.

**Question #10:** Should enhancements to CSI reporting for URLLC in multi-TRP scenarios be discussed as part of this WI?

**Summary of the inputs:**

* Seems all companies responded are ok not to handle this topic under this WI

**Proposed agreement:**

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

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | No | Leave it to MIMO group to handle. |
| Samsung | No | Rel-17 MIMO is handling this. |
| Nokia, NSB | No | Let MIMO guys to handle this. |
| FUTUREWEI | Yes | We are also ok if this is handled in Rel-17 FeMIMO WI. |
| InterDigital | No | Should be discussed in R17 MIMO |
| Qualcomm | No | This feature is better suited for the Rel-17 FeMIMO WI. |
| DOCOMO | No | Leave it to Rel-17 MIMO |
| Spreadtrum | No | Leave it to Rel-17 MIMO |
| HW/HiSi |  | Could be studied further, but as other companies pointed out, could be handled in MIMO |
| Panasonic | No | This issue should be handled in MIMO. |
| Intel | No | We understand MIMO is going to discuss this |
| vivo | No | Should be handled by MIMO session. |
| NEC | No | Should be left for handling in Rel-17 FeMIMO WI |
| CATT | No | Leave it to MIMO |
| Lenovo, Motorola Mobility | No | Better to be discussed in MIMO AI. |
| LG | No | Should be discussed in R17 MIMO |
| ZTE | No | This can be discussed in multi-TRP agenda, but not here. |
| Sharp | No | Leave it to Rel-17 MIMO |
| MediaTek | No |  |
| Ericsson | Yes | So far our understanding is, Rel-17 FeMIMO does not handle this, hence URLLC WI should pick up this since the use case is URLLC.  On the other hand, if it is determined that Rel-17 FeMIMO will handle this, we are also OK to leave this to MIMO AI. |

## Miscellaneous Enhancements

[Proposals that do not fall into one of above categories]

Lenovo [13] proposal

*Proposal 3: Consider enhancements for CSI report(s) transmission to increase its transmission possibility on one or more of the scheduled repetitions with PUSCH repetition Type B.*

CMCC [17] proposal

*Proposal 2: PUCCH enhancements should also be considered to ensure the more accurate CSI feedback.*

Qualcomm [24] proposals

*Proposal 2: Study dedicated CSI feedback for PDCCH to improve the reliability/scheduling efficiency of PDCCH.*

**Question #11:** any of above proposals should be considered as a high priority topic?

**Summary of the inputs:**

* CSI feedback for PDCCH as high priority topic
  + Yes (6): Sony, Samsung, FutureWei, InterDigital, Qualcomm, CMCC
  + No (8): DOCOMO, Nokia/NSB, HW/HiSi, vivo, CATT, LG, ZTE, Sharp
  + FFS (2): Intel, Spreadtrum

**Suggestion for discussion:**

* Study further on CSI feedback for PDCCH including
  + Identify the options
  + Evaluate the performance gain and specification impact of the identified options

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Can consider feedbacks for PDCCH. |
| Samsung | Yes | PDCCH link adaptation is more important than PDSCH one, especially for the small TBs and low latency of URLLC – cannot even receive the PDSCH without the PDCCH and the latter cannot even benefit from HARQ |
| Nokia | No |  |
| FUTUREWEI | Yes | Improved PDCCH reliability is important for URLLC. |
| InterDigital | Yes | PDCCH link adaptation |
| Qualcomm | Yes | We support the proposal:  *Proposal 2: Study dedicated CSI feedback for PDCCH to improve the reliability/scheduling efficiency of PDCCH.*  The reliability of PDCCH is essential to achieve an end-to-end reliability for both uplink and downlink. During NR Rel-16 URLLC WI/SI, the reliability of PDCCH was studied, and a new DCI format with reduced size was introduced for enhanced reliability. However, no matter how reliable the PDCCH is designed at the physical layer, without a good link adaptation scheme for PDCCH, there is no guarantee that gNB will make correct scheduling decisions on selecting the aggregation level for PDCCH (unless it always uses AL=16 for PDCCH, which obviously does not work in practice), hence leading to (consecutive) PDCCH errors.  In the current NR system in Rel-15 and Rel-16, there is no mechanism to feedback direct channel quality information about the PDCCH channel. In theory, the gNB could infer some information about the PDCCH performance based on CQI feedback for PDSCH. However, there’re severe limitations with this approach.   * The DMRS configuration/channel estimation and coding for PDCCH is very different from that of PDSCH, making it hard for a gNB to map the CQI for PDSCH to a meaningful performance indication for the PDCCH. * The interference profile is typically different between a downlink control channel and a downlink data channel.   As such, it may not be easy for the base station to accurately infer the channel quality of PDCCH from that of the PDSCH.  To guarantee the reliability of the PDCCH channel, we think having dedicated feedback information on the PDCCH channel is critical. |
| DOCOMO | No | Feedback for PDCCH can be studied further but with low priority. |
| Spreadtrum |  | Low priority for the three proposals above. |
| HW/HiSi |  | The current scope and set of questions is already rather broad, we should not expend it further at this stage.  We acknowledge that PDCCH reliability is important for URLLC, but we are surprised that it is brought up now in the context of enhanced CSI feedback. If PDCCH is improved, it should be done in a broader perspective. PDCCH reliability was on the table during Rel-15 and Rel-16 and one candidate solution was PDCCH repetition. If PDCCH reliability and transmission efficiency shall be improved, then we also should look into PDCCH re-transmissions schemes, PDCCH combining, PDCCH-ACK, etc which is out of scope of this topic. It would be better to address this issue in a more comprehensive effort in a later release. |
| Intel | No / LP | Evaluations are required to justify the need |
| vivo | No | These topics are low priority. |
| CMCC | Yes | We think it is important to enhance the PUCCH reliability to ensure more accurate CSI feedback. |
| CATT | No |  |
| Lenovo, Motorola Mobility | Yes | Our proposal can be considered as a way to reduce CSI timeline and to be more specific, it falls under the partial reporting bullet. |
| LG | No |  |
| ZTE | No for Lenovo and Qualcomm’s proposal | For Lenovo’s proposal, we do not support. It takes too much time to study this proposal which has be identified during Rel-16 and no much support on it.  For CMCC’s proposal, which has been raised in 8.3.3, it can switch to agenda 8.3.3.  For QC’s proposal, we do not support. |
| Sharp | No | Low priority |
| MediaTek | No |  |
| Ericsson | No |  |

**Question #12:** any proposal which is not captured in this summary document?

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Actually measurement based on PDSCH is not measuring the DMRS in PDSCH, but getting some soft decoding information from PDSCH, one alternative feedback way is that the information could be regarded as an additional information bundling to HARQ/NACK. This has been reflected in issue#3-1 |
|  |  |
|  |  |

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