**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 #3 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 discussion is available in R1-2007110

This document is for the second round of e-mail discussion and structured as following:

* Section 2 is revised proposals based on the first round of e-mail discussion and feedback of the proposals summarized in R1-2007110
* Section 3 is for the baseline assumptions as common evaluation methodology to study and evaluate the performance of the proposed CSI enhancement schemes.
* Sections 4-6 discusses details of proposed CSI enhancement schemes for evaluations
* Annex A include the discussion of priority issue
* Annex B include the summary of inputs for the questions discussed in the first round of e-mail discussion

Here is the color code used in this summary:

* FL’s proposals
* Questions for the inputs from companies
* FL summary of the discussions

# Proposals based on e-mail discussions

## Revised proposals from the first round of e-mail discussions:

**Observation**

A CSI enhancement for multi-TRP transmission schemes is proposed by few companies but it is currently discussed under Rel-17 FeMIMO WI. This is related to the Issue #3-2 discussed.

**FL’s Proposal #1:**

* CSI feedback enhancement for Multi-TRP transmission is not to be discussed further under IIoT/URLLC enhancement WI
  + The CSI enhancement for Multi-TRP targeting URLLC use case is expected to be studied in Rel-17 FeMIMO WI

**Observation**

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 candidate schemes with baseline assumptions commonly used by the interested companies seems to be needed. As TR 38.824 already includes the evaluation assumptions for URLLC, a subset of scenarios/assumptions can be selected as baseline assumptions.

The baseline evaluation assumption can be considered as the required minimum to be simulated for fair comparison of candidate enhancement schemes and this does not preclude companies from providing additional simulation results with other set of assumptions.

**FL’s Proposal #2:**

* 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
  + Companies can bring additional simulation results with other set(s) of assumptions
  + FFS details of baseline assumptions

**Observation**

This issue has been discussed from previous releases. A limited number of evaluations of the A-CSI on PUCCH based on CSI-RS during SI phase. Several companies raised concerns that more study and evaluations with common assumption are needed to make progress on A-CSI on PUCCH issues.

Three options have been proposed as triggering method for A-CSI on PUCCH and those options seem to be considered in evaluation as each option may provide different performance gains.

This is related to the Issue #1-1 and Issue #1-2.

**FL’s Proposal #3:**

* Companies are encouraged to study and evaluate the following options for faster CSI reporting considering performance, specification impact, and signaling/RS overhead
  + Baseline: existing CSI reporting scheme (e.g., P-CSI on PUCCH or A-CSI on PUSCH)
  + Option-1: A-CSI on PUCCH triggered by DL DCI
  + Option-2: A-CSI on PUCCH triggered by GC-PDCCH
  + Option-3: A-CSI on PUCCH triggered by PDSCH NACK (without DCI triggering)
  + Option-4: SRS triggering by DL DCI (e.g., for TDD case)

**Observation**

Lots of new proposals for CSI enhancement which have not been discussed in the previous releases. Need details of the proposals and assumptions for study and evaluation.

**FL’s Proposal #4:**

* Study/evaluate further on following CSI enhancement schemes in terms of technical benefit and specification impacts.
  + New CSI reporting type(s)
  + Reporting of additional information together with HARQ feedback (or as CSI feedback) for retransmission and/or sub-sequent transmissions
  + CSI feedback for PDCCH
  + CSI computation time reduction
  + Priority indication for P/SP-CSI and A-CSI on PUCCH
  + Subband CQI enhancements
  + Other enhancement schemes 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
  + Etc.

# Baseline assumption for performance evaluation (Phase-1)

The baseline evaluation assumption can be considered as the required minimum to be simulated for fair comparison of candidate enhancement schemes and this does not preclude companies from providing additional simulation results with other set of assumptions.

The baseline assumption discussion will have two phases:

* Phase-1: to down-select scenarios and assumptions in TR38.824 as baseline assumptions and required update in high level for the selected baseline assumptions
* Phase-2: to determine detailed assumptions (e.g., parameters) of the determined baseline assumptions if any

## General

The following categories have been identified for the proposed CSI enhancement schemes. Each category seems provides different types of gain and multiple CSI enhancement schemes in same or different categories can be used jointly for better performance.

* Cat-1: faster CSI feedback
  + A-CSI on PUCCH
  + CSI computation time reduction
  + Priority indication for P/SP-CSI and/or A-CSI on PUCCH
* Cat-2: more accurate CSI reporting
  + New CSI reporting types
  + Subband delta CQI enhancement
* Cat-3: additional information to help gNB scheduler
  + Additional information reported together with HARQ feedback
  + Event-triggered UE reporting (e.g., preferred subband, carrier, beam)
* Cat-4: enhancement for PDCCH link adaptation
  + CSI feedback for PDCCH

**Q1: do we need a different set of baseline assumptions for each CSI enhancement categories?**

* **If yes, any set of categories can share the same baseline assumption?**

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| **Company** | **Yes or No** | **Comments** |
| LG | Yes | We are generally fine with the categorization. However, between Cat-2 and 3, it would be hard to differentiate “New CSI reporting types’ and “Additional information reported together with HARQ feedback” especially when A-CSI on PUCCH with HARQ-ACK. Is it correct understanding that “CSI” in Cat-2 is confined to traditional CSI in Rel-15/16? Given that all enhancement are additional and considered to help gNB decision, it is a bit ambiguous. |
| Sony | Yes | A-CSI on PUCCH and Priority for P/SP-CSI do not seemed to fall under fast CSI category. Cat-2 and Cat-3 look like they should be under the same category. |
| HW/HiSi |  | We cannot answer with “yes” or “no” at the moment, but would firstly like to discuss about the proposed categories to get a better understanding about the purpose and also about the included sub-bullets.  For cat 1, we think some re-organization would be helpful.   * We do not think that A-CSI on PUCCH only serves to achieve faster CSI. It is also useful to reduce the control overhead. * The priority indication help to ensure that a CSI report is not dropped. It does not help to reduce the baseline CSI computation time. It can only help in the case of intra-UE multiplexing that the CSI processing time is not extended additionally. * What is meant with CSI computation time reduction in this context? Is it referred to a new CSI type that does has a reduced computation complexity, or is it aiming to achieve faster processing for the exiting CSI reports?   For cat 2,   * Could new CSI reporting types could also be included in faster CSI reporting   For cat 3, Additional information to help the gNB scheduler   * Not sure if this categories is needed as an independent category? In general and could it be associated with other categories? For example,   + With accurate CSI reports, which can help the gNB scheduled to select a more suitable MCS   + With faster CSI reports, could help the gNB scheduler to schedule more efficient retransmissions?   + With A-CSI on PUCCH, if it can help the gNB scheduler to reduce the control overhead.   For Cat-4, we are concerned that if CSI for PDCCH is included in the WI, then the scope will become too large. Here, we should at least list more details about the envisioned methods and characteristics for CSI. |
| Intel | No | Prefer a single generic set of assumptions. In that case cross-category comparisons are also possible. Furthermore, we would like to avoid discussion on category components, which seems more controversial than the overall intention to define the assumptions |
| FUTUREWEI |  | In our opinion, the current scope of study is too broad if all the schemes listed under the four proposed categories are treated with the same priority. The priority inputs from many companies collected in Round 1 should be used to assign priority to each of the schemes.  Regarding the categorization, we think the new FL proposal (merged proposals #3 and #4) is fine and should be used to update the categorization. For example, the description of the new CSI reporting type(s) in the categorization above should use the one listed in the new merged proposal #3 and #4 from FL’s email:   * + New CSI reporting type(s) based on channel/interference measurement considering aspects such as     - Reporting more accurate interference characteristics     - Reduced CSI computation time     - Reduced CSI feedback overhead (e.g., reporting interference measurement only)     - Enhanced WB/SB CQI enhancement |
| InterDigital | Yes | The agreement made on Tuesday session has one bullet on new triggering and a second bullet on new reporting types.  It makes sense to evaluate a CSI enhancement scheme for the use case in which it is expected to bring most benefits. Such use case may be different between “new triggering” and “new reporting type” schemes, e.g.   * New triggering enhancement schemes may be most useful in use cases where a data burst occurs at random time and cannot be transmitted in a single TB, i.e. larger packet sizes with random inter-arrival times * New reporting type enhancement schemes may be most useful in use cases that result in short bursts of interference, i.e. small packet sizes (32 bytes) and/or use cases with very high reliability requirements for which simple A/N-based OLLA fails (e.g. 99.9999%)   Thus, we propose correspondingly to define two sets of assumptions. |

## Performance metric

**From TR 38.824 [25]:**

**Option 1**: Percentage of users satisfying reliability and latency requirements

- Intend for the case with fixed number of UEs and fixed traffic model per UE

**Option 2**: URLLC capacity and URLLC/eMBB multiplexing capacity

- Definition: URLLC system capacity is calculated as follows:

- C(L, R) is the maximum offered cell load under which Y% of URLLC UEs in a cell operate with target link reliability R under L latency bound

- X= (100 – Y) % is the percentage of UEs in outage

- A UE in outage is defined as the UE cannot meet both latency L and link reliability R bound

- Companies report their assumption on X (either ~5% or 0%)

- Companies report their assumption on the number of eMBB UEs deployed together with the URLLC UEs

- Intend for the case that the number of UEs and/or the data arrival rate is adjustable

- Adjusting the number of UEs should be applied to periodic deterministic traffic model

**Q2: which option should be used as a baseline assumption?**

* **Please share your view per CSI enhancement category if needed (e.g., if you answered yes for Q1)**

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| **Company** | **Option 1/2** | **Comments** |
| LG | Option 1 | Option 1 is easier to compare results of evaluations with fixed number of UE. |
| HW/HiSi | Option 1 | We are not sure if we have to decide at this stage, but if required then Option 1 is our preference. |
| Intel | Option 1 | See our comments below |
| FUTUREWEI | Option 1 | Our preference is Option 1. |
| InterDigital | Option 1 | This is simpler and could be supplemented by additional metrics. |

**Q3: any new option or any modification is needed for the option selected?**

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| **Company** | **Yes or No** | **Comments** |
| Intel | Yes | The above alternatives are final metrics which require substantial simulation time and complexity to collect.  We prefer at least one simpler metrics which directly show MCS setting accuracy, such as:   * MCS prediction error, calculated as a difference of a scheduled MCS and an ideal MCS |
| InterDigital | Yes | Option 1 results should be always be shown and additional metrics should be provided:   * DL/UL signaling overhead is important since one could make baseline scheme as good as desired by reducing P-CSI and/or CSI/RS periodicity to a sufficiently small value (e.g. down to every slot). It should be shown as part of results (unless they are the same between schemes). * MCS prediction error is an additional metric that is relevant given objective of WI. |
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## Use case/requirement

**From TR 38.824 [25]:**

Table A.2-1: Representative use cases for Rel-16 NR URLLC evaluation

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| --- | --- | --- | --- | --- |
| Use case | Reliability (%) | Latency | Data packet size and traffic model | Description |
| Power distribution | 99.9999 | 5 ms (end to end latency)  Note: 2-3 ms air interface latency | DL & UL:  100 bytes  ftp model 3 with arrival interval 100 ms | Power distribution grid fault and outage management  (TR 22.804:5.6.4) |
| 99.999 | 15 ms (end to end latency)  Note: 6-7 ms air interface latency | DL & UL:  250 bytes  Periodic and deterministic with arrival interval 0.833 ms  Random offset between UEs | Differential protection  (TR 22.804:5.6.6) |
| Factory automation | 99.9999 | 2 ms (end to end latency)  Note: 1 ms air interface latency | DL & UL:  32 bytes  Periodic deterministic traffic model with data arrival interval 2 ms | Motion control |
| Rel-15 enabled use case (e.g. AR/VR) | 99.999 | 1 ms (air interface delay) for 32 bytes  1 ms and 4 ms (air interface delay) for 200 bytes | DL & UL:  32 and 200 bytes  FTP model 3 or periodic with different arrival rates |  |
| 99.9 | 7 ms (air interface delay) | DL & UL:  4096 and 10 K bytes  FTP model 3 or periodic with different arrival rates |  |
| Transport Industry | 99.999 | 5 ms (end to end latency)  Note: 3 ms air interface latency | UL:  2.5 Mpbs; Packet size 5220 bytes  DL:  1Mbps; Packet size 2083 bytes  Note: Data arrival rate 60 packets per second for periodic traffic model | Remote driving  (TS 22.186: 5.5) |
| 99.999 | 10 ms (end to end latency)  Note: 7ms air interface latency | UL&DL:  1.1 Mbps; Packet size 1370 bytes  Note: Data arrival rate 100 packets per second for periodic traffic model | Intelligent transport system (ITS)  (TS 23.501, TS 22.261) |

**Q4: which use case should be used as a baseline assumption?**

* **Case-1: Power distribution**
* **Case-2: Factory automation**
* **Case-3: Rel-15 enabled use case**
* **Case-4: Transport industry**

**Please share your view per CSI enhancement category if needed (e.g., if you answered yes for Q1)**

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| --- | --- | --- |
| **Company** | **Case 1/2/3/4** | **Comments** |
| LG | Except for Case 1 | Case 1 has lower traffic arrival rate and smaller packet size. Though it is representative case of URLLC, CSI won’t be helpful in this case. |
| Sony | Case 2 | Although all cases are appropriate, Case 2 seems to be the target for some of the objectives in the WID. |
| HW/HiSI | Al cases should be included | We should not down-select between the use cases at this stage. All use cases are representative for URLLC. Instead we prefer that companies report which use case they selected in their evaluation. |
| Intel | Case 2 | Industrial IOT and factory automation use cases can be studied with higher priority |
| FUTUREWEI | All cases could be considered | Our view is that all cases could be considered in the evaluation and companies need to report the case(s) they selected in their evaluation. |
| InterDigital | New triggering: Case 3  New reporting type: Case 2 | “New triggering” schemes may be most useful in use cases where a data burst occurs at random time and cannot always be transmitted in a single TB. This may fit “Rel-15 enabled use case” (Case 3) with 200 bytes packet size  “New reporting type” schemes may be most useful in use cases that result in short bursts of interference, i.e. small packet sizes (32 bytes) and/or use cases with very high reliability requirements for which simple A/N-based OLLA fails (e.g. 99.9999%). This may fit “Factory automation” use case. |

**Q5: for the Case you selected as baseline use case, any update in the corresponding simulation assumption table in TR38.824 (e.g., channel model for factory automation)?**

* **If yes, which assumption should be updated?**

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| **Company** | **Yes or No** | **Comments** |
| LG | No |  |
| HW/HiSi | Yes | If motion control is selected, the new indoor channel model for factory automation should be used. |
| Intel | Yes | Both deployment layout and channel model require updates to align with the outcome of InF channel model study |
| InterDigital | Yes | Agree with Intel |

## Multiplexing of eMBB and URLLC UEs sharing the same carrier

**Q6: do we need to update any assumption for multiplexing of eMBB UEs and URLLC UEs in the same carrier if Option-2 is used as performance metric?**

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| **Company** | **Yes or No** | **Comments** |
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## Link level simulation (LLS)

**Q7: do we need baseline assumptions for link-level simulation?**

* **If yes,** 
  + **which CSI enhancement category needs LLS and why?**
  + **which LLS assumption should be used as baseline?**

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| **Company** | **Yes or No** | **Comments** |
| LG | No | If necessary, we may be able to re-use LLS assumption in 38.824. |
| HW/HiSi | No | Currently we assume that no LLS are needed. |
| Intel | No | We assume MCS accuracy may be limited by interference prediction, which is hard to model by link level. Thus, SLS evaluations would be more representative and should be used as a baseline. |
| FUTUREWEI | No | If LLS is needed, we could re-use LLS assumptions in 38.824. |
| InterDigital | No | If needed, companies can bring results based on their own assumptions. |

## Transmission scheme

**Q8: do we need a baseline assumption for transmission scheme, or it is up to each company and the company reports the transmission scheme used?**

* **If yes, which transmission scheme should be used as baseline?**

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| **Company** | **Yes or No** | **Comments** |
| LG | No | At least for the discussion, it would be enough to report the transmission scheme used by the company. |
| HW/HiSI | No | Transmission scheme can be reported by the company. |
| Intel |  | We are not sure if the assumption should be fixed, but expect different techniques may be beneficial in different assumptions |
| FUTUREWEI | No | Each company can report the transmission scheme that it uses. |
| InterDigital | No | To be reported by the company. Alternatively, SU-MIMO could be selected as baseline. |

## Others

**Q9: any other assumptions we should consider as a baseline assumption?**

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| **Company** | **Yes or No** | **Comments** |
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# 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.

### 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.

**Q10: if you are a proponent of any option listed above and there is any missing detailed assumption of the option (e.g., not provided in the contribution), please provide the details here for other companies to evaluate the option.**

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| **Company** | **Comments** |
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### 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.

## 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.

## 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

**Q11: if you are a proponent of the issue #1-6 and there are any missing detailed assumptions for other companies to evaluate the option, please provide here.**

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| **Company** | **Comments** |
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**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.

# 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]

**Q12: if you are a proponent of proposal listed above and there is any missing detailed assumption (e.g., not provided in the contribution), please provide the detailed assumption for other companies to evaluate the proposal.**

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| **Company** | **Comments** |
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**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.

## 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])

**Q13: if you are a proponent of proposal listed above and there is any missing detailed assumption (e.g., not provided in the contribution), please provide the detailed assumption for other companies to evaluate the proposal.**

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| --- | --- |
| **Company** | **Comments** |
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# 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.

**Q14: if you are a proponent of proposal listed above and there is any missing detailed assumption (e.g., not provided in the contribution), please provide the detailed assumption for other companies to evaluate the proposal.**

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| **Company** | **Comments** |
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## 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], proposed 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.

### Issue #3-3

## Enhancements for PDCCH link adaptation

**Issue #3-3: CSI feedback for PDCCH link adaptation**

* Yes: Qualcomm [24], Sony, Samsung, FutureWei, InterDigital, CMCC proposed to study CSI feedback for PDCCH link adaptation

**Q15: if you are a proponent of CSI feedback for PDCCH and there is any missing detailed assumption (e.g., not provided in the contribution), please provide the detailed assumption for other companies to evaluate the proposal.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |
|  |  |

# References

1. RP-201310, Revised WID: Enhanced IIoT and URLLC support for NR, Nokia, Nokia Shanghai Bell.
2. R1-2005244 CSI feedback enhancements Huawei, HiSilicon
3. R1-2005281 CSI feedback enhancements for URLLC FUTUREWEI
4. R1-2005375 CSI feedback enhancements for Rel-17 URLLC vivo
5. R1-2005432 Discussion on CSI feedback enhancements for eURLLC ZTE
6. R1-2005514 CSI Feedback Enhancements for IIoT/URLLC Ericsson
7. R1-2005552 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
8. R1-2005570 Considerations on CSI feedback enhancements Sony
9. R1-2005634 CSI feedback enhancements for URLLC MediaTek Inc.
10. R1-2005702 CSI feedback enhancements CATT
11. R1-2005776 CSI feedback enhancement NEC
12. R1-2005870 CSI feedback enhancements in Release 17 URLLC/IIoT Intel Corporation
13. R1-2005930 CSI feedback enhancements Lenovo, Motorola Mobility
14. R1-2006059 Enhancement for CSI feedback OPPO
15. R1-2006071 CSI feedback enhancements for enhanced URLLC/IIoT InterDigital, Inc.
16. R1-2006140 CSI feedback enhancements for URLLC Samsung
17. R1-2006208 Discussion on CSI feedback enhancements CMCC
18. R1-2006276 Discussion on CSI feedback enhancements Spreadtrum Communications
19. R1-2006315 Discussion on CSI feedback enhancements for URLLC LG Electronics
20. R1-2006343 Discussion on CSI feedback enhancements Panasonic Corporation
21. R1-2006515 CSI feedback enhancements for URLLC Apple
22. R1-2006573 CSI feedback enhancements for eURLLC Sharp, NICT
23. R1-2006729 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
24. R1-2006800 CSI enhancement for IOT and URLLC Qualcomm Incorporated
25. 3GPP TR38.824, “Study on physical layer enhancements for NR URLLC”, v16.0.0.
26. R1-2006514 UE feedback enhancements for HARQ-ACK Apple
27. R1-2006799 HARQ-ACK enhancement for IOT and URLLC Qualcomm
28. R1-2007064 Feature lead summary #1 on CSI feedback enhancement for enhanced URLLC/IIoT
29. R1-2007110 Feature lead summary #1 on CSI feedback enhancement for enhanced URLLC/IIoT

# Annex A: 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

|  |  |  |  |
| --- | --- | --- | --- |
|  | **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:**

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

# Annex B: Summary of first round of e-mail discussions

Note:

* The comments from companies for the questions are captured in R1-2007110

|  |
| --- |
| **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) |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 (4): Sony, FutureWei, HW/HiSi, CMCC * 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 |
| **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 |
| **Question #10:** Should enhancements to CSI reporting for URLLC in multi-TRP scenarios be discussed as part of this WI?  **Summary of the inputs:**   * 18 companies (Sony, Samsung, Nokia/NSB, FutureWei, InterDigital, Qualcomm, DoCoMo, Spreadtrum, HW/HiSi, Panasonic, Intel, vivo, NEC, CATT, Lenovo, LG, ZTE, Sharp) responded are ok not to handle this topic under this WI |
| **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 |