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

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

**Agenda Item: 8.3.1.2**

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

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

**Document for: Discussion and Decision**

# Introduction

This contribution is a summary of contributions [2]-[22]submitted under AI 8.3.1.2 (CSI feedback enhancements) The AI is related to the following objective of the revised work item on Enhanced IIoT and URLLC support for NR [1]:

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

In RAN1#102-bis, RAN1 agreed to study/evaluate a set of CSI enhancement schemes in terms of technical benefits, specification and implementation impacts. The candidate enhancement schemes include at least new triggering methods for A-CSI and/or SRS, new reporting based on channel/interference measurement (Case 1), and new reporting based on other measurement (Case 2). RAN1 also agreed on a set of baseline assumptions for system-level simulations.

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

Here is the color code used in this summary:

* FL’s proposals
* Questions for the inputs from companies
* FL summary based on the companies’ input
* RAN1 agreements

# Collection of agreements/conclusion in RAN1 #103-e

To be captured once agreement is made during this meeting

# Proposals for 1st GTW

New reporting Case 1:

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

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

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

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

New reporting Case 2:

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

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

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

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

New triggering methods:

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

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

# Proposals for 1st check point

TBD

# Proposals for 2nd check point

TBD

# Proposals for 3rd check point

TD

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

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

## Summary of issues for Topic #1

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Observations on new triggering methods.**

For A-CSI on PUCCH triggered by DL DCI:

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

For A-CSI on PUCCH triggered by NACK

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

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

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

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

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

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

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

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

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

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi | Yes | No clarification needed to our simulations results.  In our view, our simulation results support the introduction of A-CSI on PUCCH, but they are not decisive for the introduction.  There are several benefits that also justify the introduction even without simulation, i.e.   * Efficient from the system operayion point of view. * Reducing the DL overhead compared to triggering by UL grant * Benifical for the latency, because it can be guarantted that the A-CSI is trioggered as early as possible (together with the DL assignment * Decoupling time-line for A-CSI reports and PUSCH processing time |
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**Question 1-2**: Would FL proposal 7.1-1 acceptable, considering available analysis and evaluation results? If not, would it become acceptable with different or additional condition(s)?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | Yes | Support FL proposal 7.1-1. |
| Samsung | No | A-CSI on PUCCH cannot possibly outperform SP-CSI in terms of URLLC throughout or reliability. The only new argument has been UL overhead but that is questionable given the constant overhead for the triggering information in the DL DCI and the additional padding needed in the associated UL DCI considering a TDD system. The specification complexity is substantial as well as the network complexity for preempting ongoing transmission for fast NZP-CSI-RS. |
| HW/HiSi | [yes] | We are supportive to the proposal in general. For the number of bits at this stage, the details would depend on the specific design. If it is acceptable to the group, we we would slightly prefer [X], instead of [2], and then have a note that X should be small. |
| Sony | No | The only advantage it has over SP-CSI is that it can be used to early terminate PDSCH. Apart from that, SP-CSI can do the same job. |
| Intel | No | We still don’t observe how introduction of A-CSI on PUCCH fundamentally can solve issues with URLLC transmissions. Furthermore, we analyzed the possible effect of using A-CSI for a fresh information for the purpose of retransmission scheduling, and do not observe justifying gains. |
| Nokia, NSB | No | We think that Case 1 and Case 2 reporting should be prioritized. The problem we see for doing many things is the lack of TUs. We are not against doing this if the time allows, but priority should be case 1 and 2. |
| OPPO | No | The overall evaluation results with two companies showing the gain but one company showing no gain do not provide sufficient motivation for RAN1 to move on this direction. More discussions on the simulation assumptions and results are needed. |
| LG | No | Main benefit of A-CSI on PUCCH is to reduce PDCCH overhead and it seems not to outperform comparing to SP-CSI. |
| QC | No | Beside what other companies already commented, I want to point out adding just 2 bits in DCI for this does not work. It needs much more than 2 bits. The trigger state itself may need 2 bits for 4 state (which sounds minimum). To deal with missing DL DCI issue, a “DAI”-like field is need to protect the CSI trigger, which need 1-2 bits, power control for this CSI need another 2-3 bits, PUCCH resource indication needs 2-3 bits. In total, around 10 new bits might be needed! Beside the DCI change, we also need to consider the UL prioritization rule, power control procedure, PUCCH resource selection procedure, timeline for this new CSI, out of order restriction for this new PUCCH…, just to name a few spec impact. Yet at the end, the performance gain of this feature is not well justified according to Samsung’s simulation. |
| MediaTek | No | No gain compared to existing CSI schemes. Also, using A-CSI on PUCCH for re-transmission could lead to increase in the UE power consumption and reduces the UL spectral efficiency. |
| vivo | Concern | For the bit number of DCI triggering the A-CSI report, we think it is arbitrary to conclude the number of bits in DCI. Actually, instead of the bits number, the most important thing is how to indicate the PUCCH resource for the CSI report and what is the behavior/relationship between the CSI report and HARQ-ACK feedback, and whether is feasible to have the A-CSI and HARQ-ACK transmitted in the same PUCCH occasion given the different processing timeline. These issues should be discussed and after there is a clear picture on how to indicate/trigger the CSI report on PUCCH, the number of bits in DCI can be determined. |
| DOCOMO | [Yes] | We suppot the FL proposal in general but 2bits is not enough for A-CSI on PUCCH. [X] bits is preferred at this stage and it should be further discussed in the later stage. |
| CATT | Partial yes | We agree with the proposal in general and also prefer to change [2] to [X] for further study. |
| ZTE | Yes | We believe the benefits of A-CSI on PUCCH are clear as summarized above. The submitted simulations with the performance gain further justify the necessity. We think more simulation should be provided, especially for the observation that there is no or small performance gain. At this stage, we think A-CSI on PUCCH should be supported.  The number of the bits can be further discussed. Regarding the issue of missing DL DCI, after triggering, the A-CSI should be reported as early as possible. Therefore, multiple A-CSI multiplexing is not expected and the interval between the triggering DL DCI and A-CSI should be small. The UE can assume the A-CSI can be triggered by the last DCI in most cases, which has a higher reliability. Therefore, we think missing DCI for the A-CSI is not a big issue. |
| Ericsson | Yes | Support FL proposal 7.1-1. |
| Spreadtrum | Yes | We support A-CSI on PUCCH can be triggered by DCI for DL assignmen. For bits number, we can check later. |
|  |  |  |

**Question 1-3**: If FL proposal 7.1-1 is not agreeable by the group, what way forward would you suggest? E.g. make decision in this meeting to not support? Continue evaluating until next meeting? Consider alternate triggering enhancements (such as enhanced SP-CSI on PUCCH [12] or enhanced CSI-RS/SRS triggering [21])?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Samsung |  | Conclude that no agreement to support A-CSI on PUCCH for Rel-17 URLLC. That does not mean that A-CSI on PUCCH is not useful – only that Rel-17 URLLC is not a use-case scenario justifying introduction of that feature. |
| HW/HiSi |  | We need to look at the whole picture. One possibility is as the FL said, we could consider more triggering methods. But we could also look wider than just rigegring methods. For every single isolated topic it is likely that there will be objections by someone. A different approach could be to define a whole package for the WID for which a set of enhancements is included, and the group could then converge on this package? |
| Nokia |  | There is no time to introduce this kind of triggering features as it is not that useful compared to reporting enhancement. The same applies to the enhanced SP-CSI on PUCCH or CSI/SRS triggering. |
| OPPO |  | Share the same view with Samsung. |
| LG |  | It is not necessary to enhance triggering method unless it is justified that new triggering methods makes CSI more informative in terms of URLLC. It would be fine to draw conclusion for the current situation. |
| QC |  | Conclude there is no consensus to support A-CSI on PUCCH in Rel-17 URLLC. |
| MediaTek |  | After discussing this topic in two realises (R16 & R17), it is time to reach a conclusion on not supporting A-CSI on PUCCH in R17. Continuing the discussion will not change the fact that the A-CSI on PUCCH has no gain compared to existing CSI schemes. |
| vivo |  | We would like to address the following technical issues first   1. Should the A-CSI and HARQ-ACK be included in the same PUCCH transmission?    1. if yes, how to solve the processing timline misalignement between A-CSI and HARQ-ACK    2. if no, how to determine the A-CSI and HARQ-ACK transmission timing? 2. The impact to intra-UE prioritization and multiplexing. Currently the CSI on PUCCH is always considered as low priority when colliding with other transmisisons, but the priority of A-CSI on PUSCH is determined based on UL grant. So which behavior should be followed for A-CSI on PUCCH? 3. Does the DL grant triggering the A-CSI report on PUCCH also triggers the aperiodic CSI-RS/CSI-IM for measurement? |

**Question 1-4**: Any other suggestion on how to make progress on new triggering methods?

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| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi |  | As a compromise, we could maybe support more triggering for A-CSI on PUCCH, e.g. both by DL DCI and based on NACK (based on RRC configuration). The extra specification effort would not be so much since subsequent discussions on which PUCCH resource to use are very similar. |
|  |  |  |
|  |  |  |

# Topic #2: New reporting (Case 1)

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

## Summary of issues for Topic #2

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 1. Summary of evaluation results for new reporting Case 1

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

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

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

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

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

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

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

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

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

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei |  | In our contribution R1-2100037, simulation results show that that interference observed at the UE varies significantly over time (e.g., > 6 dB with 10% probability when the time difference between two observations is >= 3 TTIs). Reporting interference statistics or CQI/SINR statistics can help gNB mitigate the impact of large variation of interference. Therefore, we would like to modify Case 1a as follows:   * **Case 1a: CQI/SINR/Interference statistics (mean, variance, etc.)** |
| Samsung |  | Do not support Case 1a: CQI/SINR statistics (mean, variance, etc.)  Reason: information can be obtained by the gNB  Do not support Case 1c: CQI using maximum interference from multiple IMR Reason: Increased UE computational requirements, increased DL overhead for IMR, mandates slower CSI updates in order to perform all measurements, unclear benefit as interference can vary from the time of measurement.  Do not support Case 1c: CQI reporting considering the worst subbands  Reason: Unnecessary new reporting type – wideband CQI + sub-band CQI for M-best subbands is optimal.  Do not support Case 1e: UE updates CQI only based on previous RI/PMI to reduce processing time  Reason: Already possible. For example, a gNB can configure CSI reports with different periodicities where one CSI report is with *ReportQuantity* = cri-RI-i1-CQI or cri-RI-CQI, and apply codebook subset restriction (doesn’t require i1 or RI report). |
| HW/HiSi |  | We think that all schemes for fast CSI computation should be considered, this means separate update of CQI and also reporting the interference covariance. These schemes are important to enhance the CSI measurement and reporting in order to provide the gNB scheduler with more accurate information for proper NCS selection.  For the prioritized use-case of factory automation it would be good to look into MU-MIMO as well. As it is shown in “3GPP TSG RAN1 WG1 email discussion [5G-ACIA], “Simulation results for 5G-ACIA in the first round”, the UE capacity can be greatly increased if MU-MIMO is used. Based on this it makes sense to also look into CSI enhancements for MU-MIMO in addition to SU MIMO.  Another issue are the sub-band enhancements. CQI considering worst sub-bands is mentioned in the proposal, but other schemes, e.g. increasing the granularity of the sub-band report are currently excluded from the proposal. Instead of going into the detailed schemes right now, it could be a good step forward to firstly agree on sub-band enhancements in general. |
| Apple |  | The Solutions in FL Proposal 8.1-1 are with different asumptions, e.g. the worst subbands are for stationary interference, and others are for more dynamic interference.  Case 1c(CQI using maximum interference from multiple IMR) is a special case of Case 1a.  On Case 1e: a UE would be required to retain all the previous CSI reports, UE complexity and memory requirement are issues to address. |
| Sony | No | No, there is no need to study other cases. We would prefer a shorter list but we are fine with the FL proposed list. |
| Intel |  | We do not think that RAN1 should spend additional efforst on other schemes. In the same time, current list could be made higher level, at least collapse two 1c schemes, which look a bit specific on its own. |
| Nokia | No | Agree with FL’s observation and proposal are from the evaluation results. We should also not fight with words here when there are results provided by companies. Everyone had their chance to provide results and show gains with the agreed simulation assumptions.  The suggestion to include interference statistics are not fully justified by the simulation results. For example, R1-2100037 results show some correlation if the time diff is short, but this is simply because they are using a traffic model with 500kByte packet size. With small URLLC packets, the “SINR-error-CDF” is nearly constant, regardless of the time difference. |
| OPPO | No | The wording for case 1e is a bit confusing given it can be understood as “CQI update is based on previous RI/PMI”, which does not seem to be the intention of [8]. It is suggested to change to “UE updates RI/PMI less frequently than CQI”. |
| LG | No | Agree with down-selecting options according to contributions in this meeting, however, it seems too detail to decide in this meeting. It would be better to remain in high level for further down-selection. |
| QC |  | We are fine to do down selection. But we are not OK with the current FL proposal.  Following what Samsung commented, each proposal should show there is a need to adopt the enhacenment. On high level, I agree with Aris, I suggest RAN1 to discuss and identify what CSI related info gNB can not derive (while UE can derive). Then we know what enhancement is necessary for Case 1.  For 1a, I think the statistics of CQI/SINR can be obtained by gNB by deriving the statistics of previous report CQI/SINR.  But for interference statistics, gNB cannot derive interference statistics, because gNB cannot see the DL interference. What gNB can estimate based on SRS is UL interference but DL interference might be very different from the UL interference.  Another measurement gNB cannot do well is Doppler estimation. UE-based Doppler estimation is more accurate than gNB as TRS and CSI-RS is design for this use-case.  gNB estimain based on SRS has a lot drawbacks:   1. UL Tx power is much smaller than gNB DL power. So SRS estimation quality is poor for gNB. (UL linkbudget is worse than DL). 2. To use SRS for Doppler tracking, we need something similar to TRS (e.g. 4 symbol gap or repetition across two slots) and this can't be made as it requies S+U slots back-to-back, exhaust UL resources. And UE can't keep phase coherent across slots, which will make Doppler estimation does not work at gNB. 3. Nokia paper in HST [R1-2101009] confirmed that that gNB’s capability to estimate Doppler from SRS is limited.   Therefore, we see a need to let UE feedback Doppler related information to indicate what is the CSI coherence time/periodicity. Otherwise, gNB may not able to setup correct CSI periodicity to sample the CSI, which may lead to under-sampling or over-sampling CSI. The proposal of CSI expiration time is to serve this purpose to help gNB set correct CSI sample periodicity.  Therefore, our view is that UE interference statistics report and CSI expiration/coherent time report are enhancement needed. However, both of them are missing in FL proposal. While there are many other enhacenments included in FL proposal but the necessity to introduce them is not clear to us. |
| MediaTek |  | First of all, it is not clear to us on which bases the moderator has selected this list. Each company has evaluated different scheme based on different assumption, hence, there is no one-to-one comparison between the results. Thus, it is not clear why if a specific metric is not reported by a company, the whole scheme is dismissed (even though other performance metrics agreed by RAN1 have been reported).  We have provided results that show better MCS selection can be achieved by using 3-bit SB-CQI reporting, where the MCS prediction error is reduced from 22% to 0.4%. Hence, 3-bit (or full) SB-CQI should be included in the list.  In our view, Case 1a (i.e. CQI/SINR statistics) shouldn’t be supported because the statistics can be obtained by the gNB from existing CSI reporting schemes. It is not clear to us how it is possible to have better performance if the UE report the SINR-STD or the worst-M SB-CQIs compared to reporting full SB-CQIs. The latter scheme provide more information to the gNB, thus, it is not possible to have worse performance. |
| vivo |  | For new reporting Case 1, we would like to clarify that Case 1e is that UE only needs to report CQI by updating channe/interference based on previous RI/PMI such that UE complexity for CSI computation can be reduced, which is beneficial for CSI processing time reduction. This is mainly for A-CSI to track the instantaneous channel/interference update. The RI/PMI can be reported with lower frequency.  Regarding the Samsung’s comments on Case 1e, in case of one CSI report config, according to current spec, CQI report only without RI/PMI updating and reporting is not supported for single CSI report config. According to the CSI report design, for CSI report config with *ReportQuantity* = cri-RI-CQI where UE reports CQI and RI, UE assumes identity matrix with normalization for the precoder when calculating the CQI.  In case of multiple CSI report configs, although gNB can configure two CSI reports with different report quantities, e.g. CSI report config 1 with *ReportQuantity* = cri-RI-i1-CQI, and CSI report config 2 with *ReportQuantity* = cri-RI-CQI, UE cannot use the PMI reported in the CSI report config 1 for calculating the CQI for CSI report config 2. In result, the CQI reported by CSI report config 2 may not be useful for gNB scheduling since there is no PMI information. That is, there would no relationship between the RI/PMI obtained in CSI report config 1 with *ReportQuantity* = cri-RI-i1-CQI and the CQI obtained in CSI report config 2 with *ReportQuantity* = cri-RI-CQI.  In addition, when codebook subset restriction is configured, the PMI or RI will be restricted by the configured subset, which is not effective to acquire the spatial information. |
| DOCOMO | No | Agree with the FL’s observation and proposal. It would be better to down-select options according to contributions in this meeting. |
| ZTE |  | We share the same view that the schemes for CSI enhancement should be narrow down due to the limited available time. We are fine with the FL proposal 8.1-1. |
| Ericsson | No | We agree that it’s necessary to down-select and focus. We can support FL propoposal 8.1-1 to make progress.  If further down-selection is explored, our preference is to focus on Case 1a and 1e. |
| Moderator |  | @Samsung: the question was about the schemes not listed. We are not trying to agree to support the listed schemes, only to study further. Based on your response I interpret that you are fine with not considering any more the non-listed Case 1 schemes.  @Futurewei: Not sure it is good idea for progress to lump “interference” with CQI/SINR statistics. This seems quite different, e.g. need to quantize from a much larger range. The simulation results provided in [2] do not seem to follow baseline assumptions either.  @HW/HiSi: I am proposing to downselect “interference covariance” because there is no result for the simulation assumptions we agreed on in RAN1#102-e. The scenario in Figure 2 of [5] includes “interfering BSs” which are not part of our agreed assumptions.  @Apple, Intel: I prefer to not recategorize or generalize too much the schemes at this point, otherwise every scheme becomes possible again and there is no progress.  @Qualcomm: We do not have any evaluation result showing that better Doppler estimation or providing interference autocorrelation would help in the URLLC scenarios we agreed on. Please note that HST is not a targeted scenario for this WI.  @HW/HiSi, Mediatek: For the “increasing granularity” schemes we are lacking results in terms of latency statistics (Option 1 of TR38.824) which we agreed on at RAN1#102-e. MCS prediction error is just an optional “additional metric”, the “mandatory” metric is missing. MCS prediction error reduction does not quantify a system-level benefit, it might be very small at the end depending on the scenario. |

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi | Yes | Our simulation results for SU-MIMO have not been captured in the FL summary. Could they please be included?  I copied the relevant text from our contribution below:   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | In scheme 1 on the CQI is updated and reported and in scheme 2 the interference covariance is reported to the gNB. The latter method is a generic approach that can be used for both SU-MIMO and MU-MIMO and is explained in more detail in the next section. The results are summarized in Table 6 below. The performance gain for the fast CSI schemes is about 42%....  Table 6 – Supported #UEs for different schemes under 100% availability   |  |  |  |  | | --- | --- | --- | --- | |  | Baseline CSI computation – 3ms | Fast CSI computation – 1ms | | | CQI only | Interference covariance | | Total UE Num. in the serving area | 70 | 100 | 100 |   ***Observation 4: Using fast CSI feedback can greatly increase the number of supported UEs. In the system level simulations for factory automation a CSI delay of 3ms has been compared with a fast delay of 1ms. About 42% more users can be supported with an enhanced scheme.*** |   We would like to have clarified why it is said in the FL summary that the simulations in [5] are not according to the baseline. In the GTW it was said that the reason is that we modeled interference. But there was not much time for further discussion during the conference call. For all schemes we simulated, we are following the baseline assumptions. It is fine and also desirable to simulate the impact of interference. As multiple companies in addition to us have pointed out, a current weakness of the CSI is to deal with the interference, therefore it is natural to simulate interference in order to show the benefits of the proposed enhancements. |
| Moderator |  | @HW/HiSi: In my understanding, “Fast CSI computation” does not correspond to any Case 1 scheme we identified in RAN1#103-e. It is not following agreed assumptions either, as explained in response to previous question. |
|  |  |  |

**Question 2-3**: Do you think the evaluation methodology and assumptions for the schemes are adequate? If not, do you have any suggestion on how to update it to (more) fairly assess the potential benefit of the proposed schemes?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| vivo | N | 1. Companies are using totally different assumptions for interference modelling. Not sure if the proposed scheme can still be beneficial when the interference assumption is changed. 2. The proposed enhancements are not compared with the basline with best performance, i.e. full sub-band reporting with short CSI periodicity. The baseline scheme for evaluation needs to be aligned among companies. |
| Ericsson |  | Companies should describe how gNB can improve link adaptation using the proposed new CSI report. |
|  |  |  |

**Question 2-4**: Any other suggestion on how to make progress on Case 1 new reporting?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi | Yes | We could categorize the schemes according to their target. Some of the schemes intend to improve the CSI accuracy for the long term channel characteristics, whereas other schemes aim to improve the accuracy of the instant CSI. After this categorization it could be easier to compare methods for the same purpose. |
| Nokia | Yes | Narrow down would help for further progress.  Based on our results, SINR statistics are better than CQI variants (checked with worst M, sub-band variants, etc.). We have not checked CQI statistics, but we do not think that would perform better than actual SINR statistics. It is intuitive to understand that SINR statistics is not an in-direct metric. Also, even though proponents of the mean- and variance-CQI are assuming those can be converted to corresponding SINR values, and it seems the fundamental assumption is still the use of SINR mean and variant.  Technically, in order to have proper MCS selection for any TB or error target, the most suitable metric would be the actual SINR statistics. |
|  |  |  |

# Topic #3: New reporting (Case 2)

## Summary of issues for Topic #3

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

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

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

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

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

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

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

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

Table 2. Summary of evaluation results for new reporting Case 2

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

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

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

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

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

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

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

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

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

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | It is unclear to us how the new reporting quantities in new reporting Case 2 could provide information about the interference at future PDCCH/PDSCH reception time due to the large variation of interference, and how the new reporting quantities can help gNB improve MCS selection for the future PDCCH/PDSCH transmission considering the low latency requirements in URLLC. |
| Samsung | Yes | As support for each proposal is very thin, it will be good to have an analysis of pros-cons for each scheme by all companies and may then proceed with 2-3 proposals having the best trade-offs.  We see little difference between evaluation results from 1-2 proponent companies and no evaluation results for the purposes of down-selection.  We also proposed to have the gNB configure the UE to append ~2 bits to the HARQ-ACK codebook for indicating the number of actual NACKs (based on TB decoding). That enables DTX/NACK differentiation which allows for OLLA and for PDCCH link adaptation with minimal overhead and no additional UE computational requirements. That proposal was not captured. |
| HW/HiSi | No | We think that the schemes for case 2 (“PDSCH decoding for OLLA performance enhancement”) are not well suited to enhance the CSI reporting in order to provide the gNB scheduler with better information for MCS selection.  The PDSCH decoding result can only give some information about the PRBs that currently are scheduled. The situation in other parts of the channel remains unknown to the gNB scheduler. Therefore, the gNB scheduler has no idea if an assignment on other PRBs might be better in the next transmission. Also, even if the next transmission is scheduled on the same PRBs again, the reported result would only be valid for a short time. If the next transmission is later (maybe 3ms after the previous), the reported information is already outdated. This is a fundamental difference compared to A-CSI reports which can report the channel state for the entire band and which can be scheduled prior to the next PDSCH transmission, so that they provide fresh information.  If the CSI is reported accurately, then there is in our view no need for enhancements on OLLA. |
| Apple |  | We can see soft NACK and soft ACK are two major directions in Case 2 study. While soft-ACK is captured in FL proposal 9.1-1, soft NACK is not captured at the same level. The categorization of Proposal 9.1-1 can be changed to  **FL proposal 9.1-1: For new reporting Case 2, continue study focusing on the following schemes:**   * **For initial transmission: Soft-ACK** * **For initial transmission: Report block error probability** * **For initial transmission and retransmission: ~~Report CQI/MCS with NACK~~ soft NACK** |
| Sony | Yes | Soft NACK & Soft ACK are two sides of the same coin. If Soft ACK is used, we would anyhow requires 2 bits giving 4 states which could easily contain a Soft NACK. So perhaps we can just call the scheme Soft HARQ-ACK. |
| Intel | No | Although the list needs further refinement / reduction |
| Nokia | No | Proposal from FL is correctly capturing the summary of the most suitable proposals for the next levels of evaluations or discussions. |
| OPPO | Yes | We have the concern for having different reporting schemes between initial transmission and retransmissions, if it is still possible for UE to mistaken the retransmission as the initial one. |
| LG | No | We are fine to downselect but it should be discussed how gNB utilize those information. |
| QC |  | Quite a few companies, QC, Ericsson, Nokia, ZTE already provided simulation results to show the gain of case 2 new report. The scheme has been there for 3 meetings. An opponent company not proving simulation results for this scheme should not be the reason to slow down the progress of this scheme in RAN1.  Regarding the proposal, we have a minor comment on the proposal, the second bullet is just an example of first bullet. The second bullet can be absorbed into the first bullet with editorial change such as “**For initial transmission: report Soft-ACK information, e.g., CQI/MCS, block error probability, number of decoder iterations, etc**” |
| vivo | No | For the new reporting case 2, it is not clear how the reporting information can benefit for the gNB scheduling for retransmission and a new transmission.   1. With the new reporting case 2, some additional information on can be reported based on PDSCH decoding for OLLA performance enhancement for retransmission. However, it should be pointed out that the information is obtained based on the scheduled frequency resource. In fact, if gNB schedules a PDSCH for a UE on a given set of PRBs and UE fails to decode the PDSCH, it would be safer for gNB to schedule the retransmission for this UE on a different set of PRBs, since UE may occur strong interference or large fading in the PRBs for initial transmission. In this sense, reporting the channel/interference information only based on the initially scheduled subbands would not be useful. 2. when the new reporting case 2 is applied for initial transmission, the reporting channel/interference information may be expired and not applicable for a new transmission if the new transmission is scheduled with a period of time after the last transmission. Especially for the burst traffic for URLLC, the reporting information based on last scheduled PDSCH decoding is not sufficient. |
| DOCOMO | No | We are fine with the down-selection. |
| CATT | Yes | We would like to further study that UE reports MCS or MCS offset in addition to HARQ-ACK to enhance OLLA. |
| ZTE |  | In our understanding, when the network receives the feedback from the UE, the feedback can be used to enhance OLLA mechanism for the next scheduling. The next scheduling could be initial transmission or retransmission, especially for a different HARQ process. Therefore, we don’t know why it is emphasized that soft-ACK can only be used for initial transmission and soft-NACK can only be used for retransmission. A clarification would be better.  SINR is another type of CQI/MCS. It can avoid the error introduced by the UE when the UE change the SINR to MCS/CQI. In addition, it may have more finer granularity than the CQI/MCS. Therefore, this raw metric can provide more precise information to the gNB so that gNB can perform more appropriate scheduling scheme for the next transmission. It is also observed delta SINR can also provide prominent performance gain in terms of the percentage of the satisfied UEs according to the simulation. Therefore, we think this method should be included and the following updates are proposed.  **FL proposal 9.1-1: For new reporting Case 2, continue study focusing on the following schemes:**   * **For initial transmission: Soft-ACK** * **For initial transmission: Report block error probability** * **For initial transmission or retransmission: ~~Report CQI/MCS with~~ soft-NACK**   For the soft-NACK, we think (delta) CQI, (delta) MCS, delta SINR can be considered and delta SINR is the best choice. |
| Ericsson | No | We can support FL proposal 9.1-1, with edits below. The list is enough for further study.  We share similar concern as several other companies, why these schemes are limited to initial tx or retx only. Thus these condition should be removed: ~~For initial transmission~~; ~~For retransmission:~~.  For 3rd bullet of FL proposal 9.1-1: suggest change to “~~For retransmission:~~ Report CQI/MCS with ACK/NACK”. In our view, the new report should be designed for both ACK and NACK. Otherwise, HARQ-ACK codebook designed will be to complicated and conditioned on UE decoding outcome. If the new report is triggered by NACK only, the report is event-based and requires blind decoding on gNB receiver. |
| Moderator |  | @Samsung: I captured the scheme “1-2 bits in a Type-2 HARQ-ACK codebook to indicate a number of NACK values” under PDCCH link adaptation. I understand that the wording of the agreement from RAN1#103-e technically allows interpretation “PDSCH decoding for OLLA PDCCH performance enhancement” but this was clearly not the intention. In any case, there is no evaluation result showing benefit for this scheme either.  @HW/Hisi: In our understand, the motivation/potential benefit for Case 2 scheme is not related to bursty interference but rather to improve OLLA considering the very low target BLER.  @Apple, ZTE: For progress it is preferable to not generalize using terms that are not well defined from the submitted input. The meaning of “Soft-ACK” is clear from e.g. [6], but in my understanding there is no clear definition/proposal for “Soft-NACK” from the submitted contributions, and no evaluation other than for the scheme of reporting (delta)-CQI/MCS or delta-SINR.  @Sony, Ericsson: As explained in [21], it is not necessarily the case that the information in case of “ACK” (Soft-ACK) would be reported together with the information in case of “NACK” (MCS/CQI). The latter information is much more urgent. So it is too early to decide to bundle the two together at this point.  @Oppo: In the schemes, the UE does not need to know whether it is initial or retransmission, but only if the result is ACK or NACK.  @QC: I understand what you mean, because “Soft-ACK” can be derived from estimation of block error probability. However, I would rather still keep them separate for now since they were evaluated separately.  @ZTE: can you clarify why you think “delta SINR” is the best choice? In my understanding, your results [3] showed big increase of resource utilization for this one, which is why I had not included it. |

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Intel |  | Question to source [12]:  Why classical OLLA based on ACK/NACK has been applied to “baseline” although it can even degrade performance, as discussed by companies? Did you check the performance w/o any OLLA only based on the reported CSI? May be the source of gains comparing to “baseline” is just in correcting the faulty ACK/NACK based OLLA? |
| InterDigital |  | Yes, we also ran without any OLLA. The results are about the same as “baseline” OLLA for AR/VR (88.1% vs 85.7%) but much worse for Factory (14.5% vs 53.3%) in satisfied UEs. |
| Moderator |  | Question to source [21]:  The resource utilization gain is shown within the “retransmission” only. What is the overall resource utilization gain over all transmissions? |

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Samsung | No | Alignment of simulation assumptions and calibration, with multiple companies presenting results, would have been proper for evaluations but it is well understood/appreciated that was not at all feasible under the current working environement and with a very large number of candidate schemes. |
| HW/HiSi | No | The simulation results are not using frequent CSI reports or CSI enhancements for comparison. Then it is difficult to see the gain of the proposed scheme for case 2.  If more studies are done, we suggest that simulations should be carried out on top of fast CSI measurement/report, or at least they should be compared with a more frequent P-CSI configuration. According to our observation, this is not done in the simulations that have been carried out in this round. The assumptions in the simulations are usually long channel coherence time (10ms) and a large P-CSI periodicity (10-20ms). Also, shorter interference bursts don’t seem to be modeled. |
| Nokia |  | We think companies should evaluate all narrow down schemes in next RAN1 meeting, and we will try to do that to enable down selection among narrow down schemes. Having lot of schemes to evaluate does not work.  In summary, in this RAN #104-e meeting, we should pick only a sub-set of schemes, based on the results provided. |
| vivo | N | We have the same concern as for case 1   1. Companies are using totally different assumptions for interference modelling. Not sure if the proposed scheme can still be beneficial when the interference assumption is changed. 2. The proposed enhancement are not compared with the best basline, i.e. full sub-band reporting with short CSI periodicity. |
| Ericsson |  | To properly evaluate the different schemes, link level simulations may be useful. In several of the companies evaluations, system level evaulations are done where it is not clearly described how the estimation of the BLEP/margin/SINRoffset is carried out. Not modelling this estimation may give results not properly showing the realistic performance of the schemes. |
| Moderator |  | @Samsung: Hopefully we can reduce the number of candidate schemes at this meeting. It would be useful to identify what simulation assumption(s) would need to be more aligned, beyond what we agreed in RAN1#103-e?  @ HW/HiSi: My understanding is that coherence time and interference bursts derive naturally from the scenarios we agreed on and which were identified as relevant for URLLC.  @vivo: Can you clarify what you mean by “different assumptions for interference modelling”? my understanding is that as long as we use the agreed assumptions and scenarios from RAN1#102-e, the assumptions in terms of interference should be same? |

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

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| HW/HiSi | Yes | According to our discussion on question 3-1 our current view is that case 2 does not need to be studied further.  It would be good if proponents of OLLA schemes can clarify how the concerns we raised in Q 3-1 can be overcome. |
| Nokia | Yes | Narrow down the category only considering initial transmission. For retransmission, it is not feasible to adjust MCS while satisfying the same TBS indication. So, it is not a realistic case for OLLA. |
| QC |  | To Nokia, soft-NACK related info is much important than soft-ACK. For ACK, OLLA still works the feedback is just side info to help base station optimize resource utilization. But for soft-NACK for reTx, it is critical information to tell base station “Your OLLA is away 10dB!” (Just an example). gNB need this info to jump start the OLLA to the correct operation point so the reTx can get through.  For reTx, with same TB and lower MCS, Yes gNB need to increase RB useage. With the new/extended RBs, gNB can play conservatively by apply additional backoff on top of the 10dB backoff it knows. |
| MediaTek | Yes | We share the same view as Nokia, the focus should be on the schemes that target initial transmission. As retransmissions occur very rarely, any gain from enhancing the re-tx will be marginal. |
| InterDigital | Yes | The gain of “retransmission-based” scheme is likely higher when the scheduler operates with a higher BLER for the initial transmission.  Suggest that we agree on a “resource utilization” metric that reflects the utilization overall all transmissions, not just for retransmissions. Otherwise, if the % of satisfied UEs is 100% it is very hard to assess the actual gain at system-level. |

# Topic #4: Other enhancements

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

## Summary of issues for Topic #4

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

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

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

**Observations for CSI feedback for PDCCH**

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

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

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

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

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

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

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

TBD

# References

1. RP-201310 Revised WID: Enhanced IIoT and URLLC support for NR, Nokia, Nokia Shanghai Bell.
2. R1-2100037 CSI feedback enhancements for URLLC FUTUREWEI
3. R1-2100102 Discussion on CSI feedback enhancements for eURLLC ZTE
4. R1-2100182 CSI feedback enhancements for URLLC OPPO
5. R1-2100227 CSI feedback enhancements Huawei, HiSilicon
6. R1-2100269 CSI Feedback Enhancements for IIoT/URLLC Ericsson
7. R1-2100377 CSI feedback enhancements CATT
8. R1-2100437 CSI feedback enhancements for Rel-17 URLLC vivo
9. R1-2100575 CSI feedback enhancements for URLLC MediaTek Inc.
10. R1-2100650 CSI feedback enhancements for URLLC/IIoT Intel Corporation
11. R1-2100790 Discussion on CSI feedback enhancements Spreadtrum Communications
12. R1-2100830 CSI feedback enhancements InterDigital, Inc.
13. R1-2100835 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
14. R1-2100856 Considerations on CSI feedback enhancements Sony
15. R1-2100881 Discussion on CSI feedback enhancements for URLLC LG Electronics
16. R1-2100994 CSI feedback enhancements for IIoT/URLLC Lenovo, Motorola Mobility
17. R1-2101014 Discussion on CSI feedback enhancements Panasonic Corporation
18. R1-2101040 Discussion on CSI feedback enhancements for URLLC CMCC
19. R1-2101202 Improving MCS Selection for URLLC Samsung
20. R1-2101379 Views on CSI feedback enhancements Apple
21. R1-2101460 CSI enhancement for IOT and URLLC Qualcomm Incorporated
22. R1-2101613 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
23. R1-2008160 CSI feedback enhancements for URLLC Samsung

# Appendix: Previous agreements

Agreements from RAN1#103-e:

Agreements

* No change of CSI processing time relative to Rel-16 CSI in this WI
* CSI processing time specific to a new CSI reporting quantity/type (if supported) can be studied

Agreement:

* For Case-2 new reporting, continue studying with focus on the new reporting type based on PDSCH decoding for OLLA performance enhancement for initial and re-transmissions of PDSCH.

Agreements:

For Case-1 New reporting, the following candidate schemes have been identified to address the fast interference change over time. Continue studying with focus on the identified schemes below for further study and evaluation.

* Scheme 1a: New reporting quantity based on CQI/SINR statistics, e.g.,
  + CQI/SINR statistics (e.g., mean, variance, etc.)
  + CSI prediction
* Scheme 1b: New reporting quantity of interference statistics (e.g., mean, variance, interference covariance matrix, etc.)
* Scheme 1c: New reporting quantity based on modifying existing reporting format, e.g.,
  + CQI reporting considering the worst subbands
  + Subband CQI granularity enhancement
* Scheme 1d: New reporting quantity related to CSI expiration time
* Scheme 1e: New reporting quantity with partial information update, e.g.,
  + CSI reporting with interference update only

Companies are encouraged to investigate the above schemes, aiming for down-selection in RAN1#104-e

Agreements from RAN1#102-e:

Agreement:

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

Agreements:

* Baseline assumptions are used as the required minimum to be simulated for the evaluation of candidate CSI enhancement schemes
  + Reuse the assumptions in TR 38.824 and TR 38.901 as a starting point
  + Companies shall report additional parameters (e.g., CSI measurement settings, CSI reporting schemes) used in their evaluation
  + FFS details of baseline assumptions
* Companies can bring additional simulation results with other set(s) of assumptions

Agreements:

* Study/evaluate further on following CSI enhancement schemes in terms of technical benefit, specification and implementation impacts.
  + New triggering methods for A-CSI and/or SRS
  + New reporting based on one or more of the following:
    - Case 1: channel/interference measurement for new CSI reporting, considering aspects such as one or more of the following:
      * Reporting more accurate interference characteristics
      * Reduced CSI feedback overhead (e.g., reporting interference measurement only)
      * Enhanced CSI reporting such as WB/SB CQI
    - Case 2: other measurement (other than channel/interference) for additional information
      * E.g., PDCCH/PDSCH decoding, recommended HARQ RV sequence, etc.
    - It targets to help gNB scheduler for better link adaptation of (re)transmission
  + [Reduced CSI computation time/complexity]
  + [CSI feedback for PDCCH]
  + Other CSI enhancement schemes that enable accurate MCS selection are not precluded
* Detailed assumptions of the proposed CSI enhancement schemes should be provided by the proponent, such as
  + Reporting values
  + Triggering conditions for the reporting
  + Associated measurement resource
  + Uplink resource to be used for the reporting
  + How to use the reported information at the gNB scheduler
  + CSI-RS overhead and CSI reporting frequency
  + CSI reporting latency/timeline
  + Etc.

Agreements:

* Consider Table 1 as baseline assumption for system level simulation for evaluating CSI enhancement schemes
  + The uses cases in Table 1 is for simulation purposes and it does not preclude a CSI enhancement scheme which is beneficial for the other URLLC use cases
* No baseline assumption is used for link level simulation
  + Companies are encouraged to use one of LLS assumption tables in Section A.3 in TR38.824 for any link level simulation

**Table 1. Baseline SLS assumption for CSI enhancement schemes in URLLC/IIoT**

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Performance metric | Option-1 (section 5.1 of TR 38.824)  Additional metrics (it is up to company to bring results with additional metric):   * MCS prediction error (e.g., difference of a scheduled MCS and an ideal MCS) * DL/UL signaling overhead * CCDF of latency samples from all UEs * BLER of 1st transmission * Resource utilization * Spectral efficiency |
| Use cases | Following two use cases can be considered for new triggering method and new reporting. Companies are encouraged to evaluate the following cases in descending priority:   * Rel-15 enabled use case (e.g. AR/VR) in TR 38.824   + Reliability: 99.999   + Latency: 4ms (200bytes)   + Traffic mode: FTP model 3 (100p/s) * Factory automation in TR 38.824   + Reliability: 99.9999   + Latency: 1ms (32bytes)   + Traffic mode: Periodic deterministic traffic model with arrival interval 2ms * Rel-15 enabled use case (e.g. AR/VR) in TR 38.824   + Reliability: 99.999   + Latency: 1ms (32bytes)   + Traffic mode: FTP model 3 (100p/s)   + Assumptions for eMBB and URLLC UEs sharing the same carrier is used (as in A2.5 of TR 38.824) |
| Simulation assumptions | Following simulation assumption is used based on the use case selected:   * Rel-15 enabled use case with UMa (Table A.2.4-1 in TR 38.824) * Factory automation at 4GHz (Table A.2.2-1 in TR38.824) with following update:   + Channel model is replaced with InF (InF-DH) in TR 38.901     - Companies can bring results with other InF scenarios additionally   + Layout is replaced with BS deployment in Table 7.8-7 in TR 38.901 |
| Transmission scheme | Multiple antenna ports Tx scheme   * Companies report the details of Tx scheme used |