**March 1st – March 26th, 2021**

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

**Title: Additional discussions on CSI feedback enhancements for enhanced URLLC/IIoT after RAN1#104-e**

**Document for: Discussion**

# Introduction

In RAN1#104-e, the following conclusion was taken for CSI feedback enhancements for enhanced URLLC/IIoT:

|  |
| --- |
| **Conclusion:** Continue evaluation of new reporting Case 1 and Case 2 for the schemes identified in Appendix B of [R1-2102131](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2102131.zip).   * Companies are encouraged to provide their views on each scheme against each criterion in respective Tables in Appendix B. * Companies are encouraged to provide additional evaluation results for as many schemes as possible, based on assumptions agreed in RAN1#102-e. * Aim for down-selection at RAN1#104-b-e by taking into account evaluation results and assessment against criteria from Appendix B. |

This document is to gather questions, comments and views in support of the evaluation of each scheme.

Companies are invited to add their input to Appendix B of this document to:

* Ask or answer questions for each scheme in “additional clarifications/details” before March 12.
* Provide their views for each criterion (Performance, complexity, specification impact, etc.) for each scheme before March 26 (note: no need to wait until March 12).

# Summary

[To be completed at the end of the discussion.]

# 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 A: Previous agreements

Agreements from RAN1#104-e:

**Conclusion:** Continue evaluation of new reporting Case 1 and Case 2 for the schemes identified in Appendix B of [R1-2102131](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2102131.zip).

* Companies are encouraged to provide their views on each scheme against each criterion in respective Tables in Appendix B.
* Companies are encouraged to provide additional evaluation results for as many schemes as possible, based on assumptions agreed in RAN1#102-e.

Aim for down-selection at RAN1#104-b-e by taking into account evaluation results and assessment against criteria from Appendix B.

Agreements from RAN1#103-e:

Agreements

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

Agreement:

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

Agreements:

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

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

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

Agreements from RAN1#102-e:

Agreement:

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

Agreements:

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

Agreements:

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

Agreements:

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

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

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

# Appendix B: Discussion templates for each scheme

## B.1.1 Case 1-1: Statistical CSI/SINR

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| --- | --- |
| **Statistical CSI/SINR [6][10][13]** | |
| New report quantity | Mean and variance CQI/SINR from a set of CSI-IM instances  (Subband or wideband) |
| Target/benefit | Scheduler gets worst-case CSI (without needing frequent CSI reports)  Scheduler gets information relevant to any TBS/BLER target (SINR) |
| Additional clarifications/details | [Mediatek] Are statistics measured only over frequency domain or over frequency and time domains?  [Nokia] we described the procedure for estimating SINR mean and std. Lot of details are [13], but mentioning (below) some details so you can refer quickly,  **Obtain frequency-domain SINR** samples by the CSI-RS measurement.  **Compute mean and std using the generated SINR samples**. Here, a further selection of SINR samples or using SINR samples when generating SINR distribution or any other method could be used for computing the mean and SINR.  **Report the SINR mean and std in the CSI report** (these are new quantities that reflect channel interference characteristics).  [QC] if the feedback is CQI statistics, why gNB can not derive it based on sub-band CQI feedback. If the feedback is SINR statistics, how can gNB use SINR information to adjust MCS, without knowing UE’s decoding performance, i.e., UE can decode which MCS at SNR X dB with 10^-5 BLER? Please notice that each UE could have different SINR <-> BLER performance depends on UE implementation. We don’t see reporting SINR can help base station. Reporting CQI statistics in theory could help because spec defined this CQI to MCS mapping table. But in practice, it is not needed neither, because 1) base station can derive CQI statistics based on sub-band CQI feedback. 2) UE could apply CQI backoff (based on CQI statistics observed at UE) via UE implementation and report more conservative CQI.  [Nokia2]  Addressing QC comment on SINR:  How can gNB use SINR information to adjust MCS, without knowing UE’s decoding performance, i.e., UE can decode which MCS at SNR X dB with 10^-5 BLER?  This is a bigger problem with CQI as it is not based on UE’s decoding performance at SNR X dB with a BLER target. At the gNB side, we use mapping of reported CQI, TB, target BLER to get accurate MCS (also w/wo OLLA). One example, when we support different TBS (256 vs 1024) the same MCS may require different SNR X values to reach 10-5 BLER, as you may know, different TBS (smaller sizes) are having different operating points, you may see Figure 4 in [13]. There are look-up tables we maintain to make things accurate as possible. However, accurate mapping is not feasible with the changing BLER targets, TB sizes, channel information not captured by CQI.  Selecting an MCS for different TBS, bler target becomes more accurate with the SINR details where we could use corresponding look-up tables to selects the best MCS without worrying too much on BLER target assumption at the UE and CQI mapping assumption of SINR operating point.  Please notice that each UE could have different SINR <-> BLER performance depends on UE implementation.  The issue you mentioned is also applicable for CQI reporting, which may be in a much worse due to the indirect nature of the report.  We agree that there will be differences between different UE vendors, between different UE models from the same vendor, and between individual devices of the same type/model. However, as we only focus on the mean and std, for a given UE, it is not difficult for gNB to derive the offset (mainly for SINR-ave. std is not changing much) the UE has from the actual SINR profile (for example, OLLA can determine such differences).  Then, UE reported SINR-ave (or adjusted), SINR-std, TB, and target BLER are used by the gNB to find the MCS accurately. The UE will not be impacted as most of these are handled by the network end.  Reporting CQI statistics in theory could help because spec defined this CQI to MCS mapping table.  CQI is not directly mapped to MCS in URLLC, and there is no use in having any table as we know. The comment is more applicable for eMBB. As we explained in an earlier time, CQI reporting assumes a TBS coming from CSI reference resource and only provided for 10-1 and 10-5 (please note this also finalized in a hurry during Rel-15, we spend a mid-night to take final decisions due to rush. Not a right solution). Many estimates are happening at the UE, where gNB interpreting the correct mapping table is not feasible. Such errors tend to make schedulers operate in a conservative manner, and performance is not good most of KPIs .  Few other points on legacy,  1) Using sub-band CQI feedback is sub-optimal because that feedback is subject to assumed TBS and assumed BLERtarget plus the UL reporting overhead is large.  2) UE should not apply any CQI backoff by itself, because UE cannot know what PHY layer BLERtarget base station applies to each TB. Note that for the same overall target BLER the PHY layer may differ between TBs e.g. because of differences in the remaining latency budget, i.e. base station may try better spectral efficiency and higher PHY layer BLERtarget if the latency budget allows retransmissions, but it must try low BLERtarget in cases where there is no time for retransmissions.  Apple: testability issues need to be addressed.  [Nokia3]  Few clarifications are required on CQI statistics [6].  1) How is variance-CQI quantity derived? Is CQI first computed for each SB and is variance then computed using mean(SB CQIs) as reference? Or is WB CQI used as reference when computing variance-CQI? Or is variance-CQI computed in some other way (not via SB CQIs)?  2) When mapping mean-CQI and variance-CQI to their SINR equivalents, what kind of fading profile is assumed? UE may suggest a given CQI index with lower mean-SINR in LOS conditions while in NLOS conditions the same CQI index would require higher mean-SINR.  [Ericsson] It seems that the main question is “why gNB can not derive it based on UE report”.  This question was addressed in [6]. If gNB relies on UE report to get equivalent information as CSI mean+std report, then the UE has to report much more frequently (15 times more frequent in [6]). This consumes more CSI reporting resources, and increase UE computation complexity for CSI. The gNB may not be able to derive CSI statistics based on such reports, since rank and PMI in reported CSI may change due to interference. Furthermore, the CSI mean+std report helps the gNB to set better backoff values in link adaptation.  [HW/HiSi]:   * Based on the answer from E///, is our understanding then correct that the main targeted benefit with this method is overhead reduction? * From the Nokia paper, we understand that one of the goals is to obtain a controlled UE behavior for the filtering of CSI measurement reports (from the paper: “Scheduler gets worst-case CSI (without needing frequent CSI reports)”. Isn’t it so that the gNB can already configure the UE accordingly, i.e. to only use the most recent resource for CSI-IM and/or NZP CSI-RS. By doing so the gNB would have even more control and can perform the filtering itself. Is our understanding correct or is there something that we are missing? * We are not sure how meaningful it is to describe the interference statistics with a mean and a variance. We would like to hear proponents view about the feasibility of this method, how applicable it is in general. For example, the interference could highly depend on the number of interfering nodes, the deployment scenario and traffic model and the scheduling decisions in the gNBs. In case the interference PDF would be asymmetrical like in the figure below, it would be difficult to describe with mean and STD.     [QC2] To Nokia, regarding the ambiguity of unknown TBS to CQI report, we don’t think the range of TBS variation is that large in URLLC, i.e., jump from 1000 to 80 bits. Why a BS would like to schedule TBS=1000 at time t, then change to TBS=80 in next slot/sub-slot?  If TBS/channel profile change drastically from time to time, we don’t see that feedback “one shot” mean SNR and SNR standard deviation (based on multiple samples in freq domain) is helpful. The reported SNR statistics at time t may be totally different from the actual SNR statistics UE is experiencing at time t+tao.  In short, if TBS/channel profile does not change so drastically, UE reports CQI assuming relative stable TBS/channel profile from CSI report to next PDSCH TX. We don’t see SNR statistics feedback is better than CQI feedback. If TBS/channel profile change drastically, neither CQI nor SNR statistics feedback can solve this issue.  Besides above, still, we don’t see how BS can map SNR to expected BLER (10^-5), as BS does not know UE’s PDSCH decoding performance (each UE can have different implementation hence different decoding performance).  [Vivo]:  Firstly, we think the mean and variance CQI can be derived by gNB if there are sufficient CQI reports, which may require UE frequently measures channel/interference and reports CSI. In this sense, the main benefits for reporting mean/variance CQI are reduction of CSI reporting overhead. We think the motivation of introducing mean/variance CQI should be justified.  Secondly, how to make use of the mean/variance CQI reported from UE by gNB for scheduling should be further clarified. Besides, how to use the mean CQI and variance-CQI is up to implementation. One may use predicted CQI = mean CQI – X\* variance-CQI, while other may use predicted CQI = mean CQI -Y \* variance-CQI, where X or Y is scale factor and X ≠ Y. How to test the performance of mean/variance CQI reporting is another issue.  Thirdly, how to obtain the mean/variance CQI in case of subband CQI reporting? If subband CQI is considered for obtaining mean CQI and variance-CQI, the variance-CQI may be enlarged due to the potential frequency selection . What advantage can be achieved compared to subband CQI report? Because gNB can schedule resource exclude PRB with the lower CQI.  Whether there are enough samples for obtaining mean CQI and variance-CQI? It seems only with the sufficient CQI samples, the corresponding statistics distribution character can be assumed. If there is no sufficient number of samples, the expected results can not be obtained.  [Intel] Examples how to calculate effective SINR or directly MCS from a reported std and mean under a given assumption of target BLER would be helpful. In our understanding, (mean – X\*std) should be used, but how X is calculated may be interesting. Also, interesting whether the filtering parameters such as window for statistics calculation are up to UE or should be controlled somehow. |
| **Evaluation results** | |
| ZTE [3]  AR/VR | Mean + stdev of CQI: 31% satisfied UEs [50%], 2.9% RU [1.9%] |
| Ericsson [6]  AR/VR (mixed) | Mean + variance of SINR (wideband): 97.5% satisfied UEs [78.5%], 76% median RU [77%]  Mean + variance of SINR (subband): 97.2% satisfied UEs [78.5%], 60% median RU [77%]  Baseline uses fixed backoff of 20 dB |
| Intel [10]  AR/VR | Mean + stdev SINR: 99.20% [99.25%] UEs for 99.99% reliability |
| InterDigital [12]  AR/VR | Mean + stdev CQI: 90.0% satisfied UEs [85.7%], 2.9 PRBs RU [1.6] |
| InterDigital [12]  Factory | Mean + stdev CQI: 100% satisfied UEs [53.3%], 2.9 PRBs RU [1.6] |
| Nokia [13]  AR/VR | Mean + stdev SINR: 1 ms 99.9999%-pct latency [2 ms], 5% RU [3%] |
| Nokia [13]  Factory | Mean + stdev SINR: ~1 ms 99.999%-pct latency [1 ms] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [QC] The baseline for comparison should be “UE apply CQI/SINR backoff (based on CQI/SINR statistics observed at UE) via UE implementation and report more conservative CQI”.  [Nokia] Meaningful benefit for statistical SINR report is shown in **R1-2008862** and **R1-2100835**. True URLLC QoS can be provided with very low overhead, which justifies the implementation/spec impact.  Suggest QC provide more information on what it means by more conservative CQI. Do you assume 38.214 defined CQI reporting method or doing extra on top of that.  [Ericsson] We are not convinced of QC view of baseline. If UE applies CQI/SINR backoff on its own, there is no way for gNB to know how much a given UE applied, and how much this backoff varies from UE to UE. The common understanding should be that UE reports to gNB the CQI that satisfies the BLER target associated with the CQI table, as described in spec. That is, not a more conservative CQI depending on UE implementation.  [QC2] Why base station needs to know how much backoff each UE applied to get the “conservative” CQI. Base station just needs to know, if following the reported “conservative” CQI, 10^-5 BLER is expected. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [QC] Yes. In our understanding, whatever algorithm base station use to adjust MCS based on CQI/SINR statistics report, UE can do similar things and reflect the adjustment in CQI report by UE implementation. On Base station side, base station can also derive CQI statistics based on sub-band CQI report.  [Company2] Views  [Nokia] UE cannot do the same thing that BS can since it doesn’t know what TBS and what PHY layer BLERtarget gNB is going to use for each TB.  R-15/16 WB CQI and SB CQI is not even close (see R1-2100835, fig 6).  [Ericsson] As explained above, there is no equivalent mechanism in Rel-15/16. The proposed statistical CSI report is a substantially better way compared to existing scheme. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] High impact on UE implementation. Please see the aspects mentioned in “specification impact”  [Nokia] Medium impact to UE implementation: SINR mean and std must be estimated from CSI-RS and CSI-IM. To estimate the interfered conditions, we have used the worst 8 PRBs (comparable to using worst 2 subbands).  [Ericsson] Low impact to UE implementation. In our proposal, RI and PMI are not evaluated for statistical report (i.e., assume the same as last CSI-RS/IM occasion). We assume that CQI is evaluated the same as existing mechanism. The only new step is to calculate mean and variance of CQI.  [vivo] to obtain the sufficient CQI samples, more frequent CQI measurement is required. |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] High impact to spec. Need specify the following: what CQI/SINR statistics to report. What is the report format? Quantize the report in how many bits? How does UE derive the report? Any enhancement on CSI-RS configuration to support this new report?  [Nokia] Low. Specification impact is only expected by adding new reporting of SINR-std and SINR-ave quantities in a CSI-report. Legacy CSI framework can be used with the same measurement, computation timelines, reporting modes, and other details. We can expect low impact compared to many other proposals.  [Ericsson] Low impact to spec according to our proposal. No new CSI-RS/IM configuration is required. No change to CQI determination procedure.  Issues like how to report (report format, how many bits to quantize to) cannot be avoided regardless of which new CSI is to be specified. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Company1] Views  [Nokia] Yes, in the specification, there should be details giving guidance on how the CSI quantity is calculated (this is valid for any CSI quantity). In SINR-stats, we have to define UE assumptions and some details (are provided in section 8.4 reply and also in **R1-2100835)**. As SINR is a direct metric, it may suit more for inter-operability than legacy CQI report (where specific estimate on BLER targets are assumed and different UEs may use different principles). For example, CQI determination is mentioned in 38.214 by assuming CSI reference resource, but how the UE assumes CQI for a given BLER target is not defined.  [Ericsson] With our CQI statistics proposal [6], there is no issue of testing and inter-operability, since the CQI determination procedure is the same as currently defined. |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] Not mature yet. It is just a high level concept. Many details are missing. Please see the questions listed in spec impact.  [Nokia]: SINR is a well-known metric, compared to many others. Getting average and std should not be something fancy. Details are provided in R1-2100835. Design perspective NR framework is used as the legacy procedure. It is only a new CSI reporting quantity (same with all other options). We think this is not a big issue for all proposals. Disagree with QC.  [Ericsson] Case 1-1 as described in [6] is more mature than most other Case 1 schemes. The only missing piece that needs to be standardized is a report mapping table for the statistical CQI. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] Yes  [QC] No. Like we mentioned, this scheme can be achieved by UE/gNB implementation.  [Nokia] Yes,  We should take technical details into account than companies say No.  We explained the comments above, and it would be good to consider them.  [Ericsson] Yes. This method is far better evaluated than many other schemes. Performance improvements have been observed by quite a few companies’ independent study. |

## B.1.2 Case 1-2: CSI prediction

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| --- | --- |
| **CSI prediction [21]** | |
| New report quantity | CSI for a set of future instances |
| Target/benefit | Scheduler gets CSI closer to actual CSI for the PDSCH scheduling instance |
| Additional clarifications/details | [Nokia] This may not be feasible to simulate without extra details on what kind of methods are assumed for predictions?  How is the UE using past information for predictions?  Also, what is reported as CSI, all CSI quantities, or we focus only on CQI?  [Ericsson] How to pick future time instances (T1, T2 ….) without knowing when gNB will schedule? What’s the predicted CQI/RI/PMI (should be a range of possible values)?  [HW/HiSi]: In our understanding, we are not sure if interference can be predicted accurately. An implementation based method also exists already (pre-scheduling). The interfering gNBs can “announce” the upcoming PDSCH transmission, i.e. the interfering BSs transmit at slot *n* a NZP-CSI-RS to simulate the scheduled PDSCH at slot *n+x*. In other words, the NZP-CSI-RS will have the same transmit power, resource allocation, and precoding matrix as the scheduled PDSCH will have at TTI n+x.  [Sony] Is a way CSI or rather CQI are prediction of future radio conditions. By the time UE reports the CQI the propagation condition already changed and so the gNB would have mechanism to decide how valid this CQI is for its future scheduling. Hence, it isn’t clear that this would offer benefit to what we already have today.  [QC] Assuming the CSI at t and t+tao follow a joint prob distribution such as Gaussion distribution, given CSI measurement at t, UE can predict the CSI at time t+tao, with a certain confidence level (say CQI>X with 99.999% confidence level), UE then report CQI=X. The parameters for the Gaussion distribution can be estimated based on measurement on CSI-RS.  [ZTE] How accurate is the CSI prediction based on the proposed method? How does the network use the reported CSI? For example, does the network use the reported CQI directly without any adaptive adjustment because the reported CSI reflects the future channel quality or the network can also further make some adjustments further based on the reported CSI, e.g. according to OLLA?  [Vivo] we also think interference is time-varied and can not be predicted accurately. All the CQI used by gNB in the scheduling time is estimated and assumed. So there is no difference between the predicted CQI and the reported CQI.  [Intel] Any clarifications on how the interference predication could work in a bursty traffic scenario are helpful. |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No evaluation results  [Company1] Views  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Samsung] gNB implementation based approaches exist  [QC] gNB does not know interference information so gNB implementation based prediction does not work well.  [Ericsson] It’s unclear if there is any benefit since no evaluation results are provided. Existing UE/gNB implementation essentially performs prediction at gNB side, taking into account CSI report from UE.  If switching to prediction at UE side, there are several issues. The UE does not know any information about when/how/what gNB will schedule, e.g., the future time instance, the target BLER scheduler needs to achieve, PRB allocation. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] There is no sufficient details of the method. Hard to judge the impact on UE/gNB implementation complexity. How should gNB schedule “multiple back-to-back CSI-IM resources for interference measurements”? How are the future time instances (T1, T2, …) decided? How to specify in the spec the predicted CSI for a future time? How can gNB use the prediction by UE?  [Company1] Views  [Company2] Views |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Samsung] Does not appear specifiable  [Ericsson] Unclear how this can be specified. Are different UEs allowed to predict CSI (e.g., backoff amount) their own way?  [QC] Spec impact is small. In additional to report a CSI follow today’s spec, UE attached another predicated CSI. How to predict the CSI is UE implementation.  [Company2] Views |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Samsung] Does not appear testable  [Ericsson] Not testable.  [Company2] Views |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] Not mature. Many details are missing.  [Company1] Views  [Company2] Views |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] Yes  [Nokia] no discussion or details above to study this further.  [Ericsson] No. The scheme is merely sketched out without details. Simulation results for this scheme have not been provided for last two meetings. |

## B.1.3 Case 1-3: Interference statistics

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| **Interference statistics [2]** | |
| New report quantity | Mean/variance/max of interference-to-noise ratio |
| Target/benefit | Scheduler gets worst-case CSI (without needing frequent CSI reports)  (Scheduler can decide how aggressive MCS setting can be)  [Ericsson] Why the method has the above benefit (Scheduler gets worst-case CSI)? Shouldn’t it depends on exactly which statistics is used (min, max, x% …)? |
| Additional clarifications/details | [Nokia] We assume this is related to Case 1-1, where SINR statistics can also capture interference statistics?  SINR statistics mentioned in case 1-1 could also contain the case that the channel (CMR) is assumed not to vary compared to interference.  [OPPO] Similar question as from Nokia. If case 1-3 is applied in practice, would it be better or even require to work together with Case 1-1? In other words, would case 1-3 be an independent proposal here?  [Ericsson] Agree with Nokia/OPPO that CQI/SINR statistics in Case 1-1 takes into account interference statistics.  [HW/HiSi] It would be good if the difference of 1-1 and 1-3 could be clarified, in our understanding CQI as in 1-1 is based on a certain PMI and RI, while SINR only needs the information about the interference.  [vivo]: CQI/SINR statistics is mainly based on interference statistics. We think case 1-3 can be combined with case 1-1 to reduce the number of candidates.  [Intel] Similar to SINR statistics, it would be instrumental to understand at least one example how the statistics is used to calculate effective SINR of directly MCS for a given target BLER. Also, interesting whether the filtering parameters such as window for statistics calculation are up to UE or should be controlled somehow. |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No evaluation results provided |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No evaluation results to show the benefit. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Samsung]  [QC] high. Please see the spec impact  [Ericsson] High impact.   * Resource for interference measurement needs to be provided by gNB. * Unclear how the gNB can use the reported statistics in the scheduler, since the interference measurement is taken outside of CQI. The gNB does not know how good UE implementation handles the interference, and does not know how to modify CQI according to the reported INR. * New concept of interference statistics (e.g., INR) needs to be introduced. New measurement and new reporting for UE. |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] high spec impact. Need define: what intf statistics quantity to report? How to derive the report? Any new CSI-IM resource needed? Bit width and quantization for the report.  [Ericsson] High spec impact. New concept of interference statistics (e.g., INR) needs to be introduced. New measurement resources, new measurement procedure, new report formats are to be defined. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Samsung] “Statistical CSI/SINR” has clearer testability.  [Ericsson] Not testable |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Samsung] “Statistical CSI/SINR” is better defined.  [QC] This is a high level idea only. It is not mature yet. Many details are missing.  [Ericsson] Not mature. Many details are missing. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] Yes. This is different from CQI/SINR statistics where base station can derive. Base station can not derive UE interference info. So this can be further studied.  [Ericsson] No. |

## B.1.4 Case 1-4: Interference covariance matrix

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| **Interference covariance matrix [5]** | |
| New report quantity | Interference covariance matrix |
| Target/benefit | Reducing CSI processing time because only interference is updated.  Scheduler gets CSI closer to actual CSI for the PDSCH scheduling instance.  Support of SU-MIMO and better MU-MIMO support. |
| Additional clarifications/details | [Nokia] Is not this covariance matrix also related or impacted by the UE's assumptions on interference cancellation?  It would be good to have further details on any quantizations assumed on feedback and how this feedback is used for MCS selection.  [HW/HiSi] An MMSE-IRC receiver is assumed. Based on the obtained interference matrix A, the gNB can estimate the received SINR at the UE side for the selected precoding matrix W since the gNB has all the UE information available, at including the precoded DL channel (H\*W), the interference matrix A and the noise. Then it can select a MCS index matching the estimated SINR perfectly.  [vivo]: Does this option specify explicit quantization and feedback of covariance matrix? MU is not typical case for URLLC scenario. |
| **Evaluation results** | |
| Huawei [5]  Factory (non-baseline) | 160 supported UEs [100], 38% RU [100%] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Samsung] MU-MIMO is challenging even for eMBB, not appropriate for sparse ultra-reliable traffic. Feedback overhead and required accuracy inappropriate for URLLC.  [QC] Feedback overhead is too large.  [OPPO]: Share similar view with Samsung  [Ericsson] MU-MIMO with strong interference is not appropriate for URLLC traffic. The proposed new CSI report of covariance matrix incurs excessively large overhead.  [HW/HiSi to SS and Oppo]; If MU-MIMO is challenging for URLLC depends on the use case and deployment scenario. It might be true that that this scheme is not so suitable for sparse traffic, but for a controlled environment in IIoT, it can be used to enhance the capacity.  [HW/HiSi to QC and E///]; Disagree, the overhead depends on how the interference covariance is reported. For example the entry of a predefined matrix could reused for that. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No  [Company2] Views  [HW/HiSi] No |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] High impact to both UE and gNB implementation. For UE, interference covariance estimation at matrix level is required. At gNB, we don’t see a good way that the gNB can use such report, but it’s clear that the link adaptation has to be completely redesigned.  [HW/HiSi] Moderate. On the UE side, the interference matrix needs to be calculated as part of the legacy CQI calculation, it is not an extra burden. And also for the gNB we have explained the usage in [5], the complexity is not large and in some cases even absorbed in other calculations when the rank and/or the precoding matrix is adjusted. |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] high  [Ericsson] High spec impact.  [HW/HiSi] Moderate |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] Not testable  [HW/HiSi] It is testable. The same mechanisms as currently testing PMI can be used. For example the interference co-variance matrix is quantized and the index is fed back. There should be no issues that prevent testing. |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] this is just a high level idea. Many details are still missing.  [Ericsson] Not mature. Many details are missing. The individual UE implementation aspect that’s considered in current CQI report is missing. It’s not clear how gNB can utilize the new interference covariance matrix report.  [HW/HiSi]. The concept is quite simple and the interference information is already available at the UE for calculating the CQI. One thing we need to agree, though, is the signaling of the interference to the gNB. Here we think we can re-use an existing approach and report the entry of a pre-defined matrix. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] No  [OPPO] No  [Ericsson] No. We agree with Samsung that MU-MIMO is challenging even for eMBB, especially for FDD. This scheme is better handled within eMIMO, e.g. MTRP and FR1 FDD reciprocity.  [HW/HiSi] Yes, MU-MIMO for URLLC is an important and feasible approach to increase the capacity for in IIoT. This has been verified in simulations. Also, if our understanding of 1-3 is correct, then 1-4 might be similar to 1-3, in both cases interference is reported and these methods could be studied together. |

## B.1.5 Case 1-5: CSI based on worst IMR occasion

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| **CSI based on worst IMR occasion [3]** | |
| New report quantity | CQI from the CSI-IM occasion with maximum interference within a set of CSI-IM occasions. |
| Target/benefit | Scheduler gets worst-case CSI (without needing frequent CSI reports) |
| Additional clarifications/details | [Nokia]: Is this require more frequent CSI-IM compared to CMR?  [HW/HiSi] Is our understanding correct that this scheme could also be classified as providing interference statistics?  [ZTE] response to the question from Nokia: Compared to CMR, either more CSI-IM or the same CSI-IM can work. Anyway, the UE just uses the maximum interference within the filtering window for the CQI calculation.  Response to the question from HW/HiSi: Yes, it can be seen as a type of interference statistics, e.g., the CQI based on the maximum measured interference within a duration.  [Intel] Whether this is just a special case for interference statistics and may need to be combined with B.1.3 Case 1-3. |
| **Evaluation results** | |
| ZTE [3]  AR/VR | 58% satisfied UEs [50%], 2.3% RU [1.9%] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Samsung] gNB can do conservative scheduling if so prefers based on average and more accurate CQI reports.  [QC] Yes, gNB can do scheduling more conservatively.  [Nokia] It is sufficient for the gNB to adopt conservative link adaptation to achieve comparable performance to what would be achieved with this scheme. Additionally, more useful information can be derived from multiple IMR occasions, e.g., SINR/CQI/interference statistics.  [Ericsson] Yes, gNB can apply different amount of backoff. If desired, gNB can apply more backoff to account for the worst IMR. On the UE side, it is up to UE how to select the CQI value. The existing UE could select the CQI value taking into account the worst IMR over a time window.  [ZTE] The purpose is to achieve the conservative and **efficient** scheduling. Without some useful information, the network has to schedule as conservatively as possible to ensure the reliability. It leads to the waste of resource. This method can provide the information such as the worst CSI to the network. In this case, the network can know how conservative scheduling is used while the resource efficiency can also be ensured. More specifically, the CQI based on the maximum interference among multiple interference measurement samples is the lower bound. With this information, the network does not schedule with lower MCS compared to this reported worst CSI. Therefore, considering the resource efficiency, the benefit cannot be achieved by UE/gNB implementation. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Samsung] Feasibility is unclear as interference needs to be filtered for accuracy  [Company2] Impact to UE implementation maybe medium/low. UE need to measure multiple IMR and use the worst one.  [ZTE] The impact on the UE/gNB implementation is limited since the interference processing is needed anyway. For the current CSI, the interference should be filtered and it is up to UE implementation. The current CSI and this new CSI can be configured at the same time. If the network requires the CSI based on the filtered interference, the current CSI should be configured. |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] Need specify how to define worst IMR.  [ZTE] The CSI based on the maximum interference is specified. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Nokia] Yes. We do not see any concern on the testability of the proposal.  [Ericsson] No. How to tell that the UE used the worst IMR in choosing CQI entry? It is completely up to UE implementation to generate the CQI. The UE could use a conservative backoff together with existing CQI report, and deliver the same CQI as using worst IMR.  [ZTE] Response to the comments from Ericsson: It can be configured by the network. For example, a new CSI type is defined, where the UE use the worst IMR to determine the CSI and this CSI is reported using the new defined CSI type. For the current CSI type, it is up to UE implementation to generate the CQI. |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] Relatively simply scheme, looks mature.  [Ericsson] The description of the scheme is not very clear. For the simulation example(s) in Table 2, over the period of 10 slots, the worst IMR over the duration of 10 slots is selected, but channel quality is estimated for each slot individually? Or: this scheme is a variant of Case 1-1 (statistical CSI/SINR) where the statistical measure is “min”?  [ZTE] In the simulation, the period for the CSI-RS is 10 slots. The filtering window is a long duration, for example, 60 slots. The worst IMR is selected among all the measurements results within this window. The channel quality is estimated every 10 slots.  In our understanding, this scheme is a variant of Case 1-1, where min CQI is reported as the statistical result.  The proposal is simple and mature since the only change is the interference processing at the UE side |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] Yes, it seems this scheme falls into same category as 1-6 and 1-7. They can be studied together  [Nokia] Yes.  [Ericsson] No. The scheme can be achieved by existing UE and/or gNB implementation.  [HW/HiSi] If studied further, could it be considered as one candidate for interference statistics?  [ZTE] Yes |

## B.1.6 Case 1-6: Worst-M CQI

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| **Worst-M CQI [13]** | |
| New report quantity | CQI corresponding to transmission over Worst-M subbands |
| Target/benefit | Scheduler gets worst-case CSI (without needing frequent CSI reports) |
| Additional clarifications/details | [Samsung] Why can’t the scheduler just use the best subband?  [Nokia] The idea is to report CQI associated with the worst-M sub-bands for the defined target BLER, in addition to the wideband CQI. In our observation, there is high variation on the sub-bands interference levels with time and knowing best sub-bands are not fully allowing to schedule the UE on those as in the next instance you may get bad interference on those sub-bands. The idea is to get worse-M CQI to understand how bad interferences can be and somewhat use random scheduling across full band with a MCS selected based on worst-M CQI. We tried out different scheduler considerations on how to use different CQI types and did not find that best-M or reporting best\_M subbands are that useful. We would say this can be due to the randomness of interferences across all sub-bands.  [OPPO]  Q1. Our understanding is that case 1-6 is to report a “block list” to gNB, instead of an “allow list”. So the basic rational here is that the scheduling based on zero-information on sub-bands other than ones in “block list” (i.e., a restricted random scheduling) is better than the scheduling based on reported information on sub-bands in “allow list”. Is this the right interpretation of the idea?  Q2. What is the criteria to determine M so that the majority sub-bands out of the “block list” would not be as [almost] bad as the one in the “block list”? Should gNB and UE have a negotiation protocol to determine M?  Q3: Is case 1-6 an independent solution or it still needs some other accompanied reports eventually?  [HW/HiSi] Is it correctly understood that this scheme is mostly aiming for an overhead reduction? Already now, multiple sub-band could be reported and the gNB could select a MCS according to the worst sub-band for scheduling the next transmission.  [ZTE] Does this report replace the current sub-band CQI report finally? In the current sub-band CQI report, the network can also know the CQI corresponding to the worst M sub-bands.  [vivo]: Current sub-band CQI report has include the worst CQI. Is this scheme for overhead reduction?  [Intel] We are also interested whether this only targets the modes with WB CQI, since SB CQI is already possible in different scenarios, where the worst SB can be determined by gNB. |
| **Evaluation results** | |
| Nokia [13]  AR/VR | Worst-2 CQI: 1 ms 99.9999%-pct latency [2 ms], 5% RU [3%] |
| Nokia [13]  Factory | Worst-2 CQI: ~1 ms 99.999%-pct latency [1 ms] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Nokia] Meaningful benefit for worst-M CQI report is shown in R1-2008862 and R1-2100835. True URLLC QoS can be provided with very low overhead, which justifies the implementation/spec impact. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Company1] Views  [Company2] Views  [Nokia] No. See R1-2100835.  [Ericsson] No  [HW/HiSi]: Our current understanding is yes. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] implementation impact is low/medium  [Nokia] Low.  [Ericsson] Low |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] spec impact is low/medium  [Nokia] Low.  [Ericsson] Medium/low. Specifications are needed to provide value M. The CSI report is extended to include a second CQI value.  [HW/HiSi]: Medium |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Nokia] No issues are visible on Testability.  [Ericsson] yes |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] This seems a relatively simple scheme. It is mature enough  [Nokia] No sub-options. Clear proposal.  [Ericsson] Mature. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [QC] it seems this scheme falls into same category as 1-5 and 1-7. They can be studied together  [Nokia] Yes  [Ericsson] Yes  [HW/HiSi]: We have the understanding that this scheme is already achievable with Rel-16. In that case we would say “no”. But we might have misunderstood and would like to understand why e.g. according to Nokia this is not possible with Rel-16. |

## B.1.7 Case 1-7: Worst-best criteria for subband CQI report

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| **Worst-best criteria for subband CQI report [21]** | |
| New report quantity | CQI for each of K worst subbands. CQI for each subband is best across CSI-RS resources |
| Target/benefit | Scheduler gets worst-case CSI (without needing frequent CSI reports) |
| Additional clarifications/details | [Samsung] Why can’t the scheduler just use the best subband?  [Nokia] Is this required to indicate the worst K sub-bands together with the CQI? We do not find details in [21], and it would be good to have more information on what is carried as the CSI report?  [OPPO] We have same questions here as we have for case 1-6. More information is needed for the solution itself, especially the key difference from case 1-6.  [HW/HiSi]: The motivation for the worst sub-band seems similar to scheme 1-6. However, what is the motivation to report the best subband CQI in this case?  [QC] Indeed, there are some similarities between case 1-6 and case 1-7. But Case 1-7 extend 1-6 from 1-dimension (subband) to 2-dimensions (CSI-RS resource, and subband). In case 1-6, it seems only 1 CSI-RS resource is configured. UE then measures multiple subbands and report the worst-M subbands. With case 1-7, multiple CSI-RS resources are configured. Case 1-7 can be viewed as 2 step approach. In step 1, for each subband, the best CQI cross the CSI-RS resources are selected. Step 2 just does the same thing as case 1-6. In other words, case 1-7 = step 1 + case 1-6. In terms of report quantities, in additional to worst-M CQI, UE needs to report the CSI-RS resource index associated with the reported CQI for each subband.  The motivation to introduce step 1 is to give gNB some information on which are the best DMRS ports (inferred from the reported CSI-RS res indices) on the “worst” subband should be used to schedule URLLC traffic.  [ZTE] Does this report replace the current sub-band CQI report finally? If the purpose is to get CQI report for the worst sub-bands, is only the worst CQI (for the worst sub-band) is enough?  [vivo] Same question as for Case 1-6. |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No simulation results    [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No  [Company2] Views |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] low/medium  [Ericsson] Low/Medium |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] low/medium  [Ericsson] Medium. The parameters K, M, N are to be specified. It’s to be defined how to report the worst K CQI values. Is some type of wideband CQI reported, and the worst K CQI values are reported as differential to the reported wideband CQI?  [QC2] To Ericsson, the worst K CQI values report is the same as in case 1-6. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] yes  [Company2] Views |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] This is a relative simple scheme. It is mature enough.  [Ericsson] The scheme is relatively simple. However, there are many sub-options in choosing a sub-set of CQI values among the M\*N values. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [QC] it seems this scheme falls into same category as 1-5 and 1-6. They can be studied together  [Ericsson] This scheme is similar to 1-6, and can be studied together. |

## B.1.8 Case 1-8: 3-bits differential subband CQI or 4-bit full subband CQI

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| **3-bit differential subband CQI or 4-bit full subband CQI [5][9]~~[13]~~** | |
| New report quantity | Differential subband CQI with 3 bits or full 4-bit subband CQI |
| Target/benefit | Reduced MCS prediction error from quantization  More accurate subband information |
| Additional clarifications/details | [Nokia] CQI is reported per BLER target and TBS assumption, and how will this enhancement be used when selecting proper MCS selection for different TBS and BLER targets?  [HW/HiSi] CQI, target BLER, TBS, and SINR have implementation dependent relationships. At the UE side, the target BLER, TBS and SINR are utilized to obtain the CQI, while the gNB can recover the SINR from CQI, TBS, and target BLER. So, once the gNB receives the CQI for a particular target BLER and TBS, it can also choose a MCS for a different TBS. That means that even if the CQI is measured based on TBS1 and target BLER1 at the UE, the gNB can also get MCS for TBS2, target BLER1 based on reported CQI.  [Intel] in our expectation, more accurate sub-band reporting does not directly handle interference burstiness problem. Any comments on this? |
| **Evaluation results** | |
| Mediatek [9]  Factory | 3-bit D-subband CQI: 0.4% of incorrect MCS [22%]. Baseline uses 2-bit D-CQI |
| Nokia [13]  Factory | 4-bit subband CQI: 1 ms 99.9999%-pct latency [2 ms], 6% RU [3%]  [Nokia] The results were provided compared to Case 1-1 and Case 1-6, where those proposals have much lesser resource utilization. |
| Intel [10]  AR/VR | 4-bit subband CQI: 99.05% [99.25%] UEs for 99.99% reliability |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Samsung] Some benefits are shown  [Ericsson] The evaluation results do not show significant performance benefit [10][13], especially in light of the almost doubled CSI overhead [13]. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] The proposal extends the existing report by giving it 1 or 2 more bit to improve granularity.  [Company2] Views |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] yes  [Company2] Views  [HW/HiSi]: Yes |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Samsung] Scheme is well defined and easy to simulate  [Ericsson] The scheme is mature. The only design issue is to build the extended mapping table for 3-bit or 4-bit differential CQI for subband.  [HW/HiSi]: Simple and easy to understand. The granularity of the sub-band CQI is improved. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] Yes  [Ericsson] No. Considering the evaluation results in [10][13], better methods exist to provide similar performance benefit without the substantial increase of reporting overhead.  [HW/HiSi]: Yes |

## B.1.9 Case 1-9: Reference wideband CQI excludes worst subbands

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| **Reference wideband CQI excludes worst subbands [9]** | |
| New report quantity | Existing 2-bits D-subband CQI formats or 3-bits D-subband CQI format |
| Target/benefit | Reduced MCS prediction error from quantization |
| Additional clarifications/details | [Nokia] How the gNB interpret the sub-band CQI report without sub-band information?  How will this information be used in the scheduler as interference is random (see e.g. R1-2100835 figure 2) and reported sub-bands may experience interference in the next scheduling instances?  [ZTE] Are the sub-band information reported as well? For example, which sub-bands are excluded. Does this method replace the current sub-band CQI report finally?  [vivo]: Whether subband CQI is lost when reference wideband CQI excludes worst subbands? Whether it impacts on gNB scheduling scheme? |
| **Evaluation results** | |
| Mediatek [9]  Factory | Reported enhanced wideband CQI better than baseline wideband CQI 62% of time |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] The CQI histogram is shown in [9]. However, there is no evaluation of how this eventually improves performance like BLER.  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No  [Company2] Views |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Ericsson] The scheme as described has low impact to spec. However, similar to Nokia, we also question why the indices of the best subbands are not reported; and if not reported, it’s not clear how gNB can schedule with the enhanced wideband CQI. If the indices of best subbands are to be reported, then impact to spec and reporting overhead increase.  [Company2] Views |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] Yes  [Company2] Views |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] Mature  [Company2] Views |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Ericsson] This scheme can be further studied together with 1-6, 1-7.  [Company2] Yes/No |

## B.1.10 Case 1-10: CSI expiration time

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| --- | --- |
| **CSI expiration time [21]** | |
| New report quantity | Delay after which auto-correlation of CQI falls below threshold |
| Target/benefit | Scheduler gets correct sampling time for CSI reports |
| Additional clarifications/details | [Nokia] CSI expiration time does not quantify the impact of interference in terms of interference dynamic range?  Also, CSI expiration time informs the gNB of the time range over which a reported CQI is valid. Does it provide any additional information that would help the gNB to adapt its MCS selections better?  To compute auto-correlation for CQI or any other CSI quantity, we expect that TDMed transmission of multiple CMRs and/or IMRs would be needed. Using the same measurement resources, other proposals e.g., interference statistics, CQI/SINR statistics., provide information enabling to bound the dynamic range of the interference as seen by the UE, which we see as the main lever to enable improved MCS selection.  [HW/HiSi]: Is the main purpose of this functions that the gNB shall get assisting information how to set CSI feedback periodicity?  [QC] To Nokia: CSI expiration time does take the impact of interference into account. It is derived based on measuring both CMR and IMR.  To Nokia and HW/HiSi: CQI/SINR/intf statistics feedback alone cannot achieve the objective of “CSI feedback enhancements to allow for more accurate MCS selection” in WID, because gNB does not know when to request CSI feedback, i.e., what is the periodicity for P/SP CSI feedback, when to schedule A-CSI feedback. The CSI expiration time report can resolve this issue. It helps BS to decide the periodicity for P/SP-CSI and timing for A-CSI feedback. With that, BS can use the most recent/ CSI feedback, rather than an outdated CSI feedback, to make the correct MCS decision in scheduling.  [ZTE] In our understanding, CSI expiration time is estimated based on the autocorrelation of the channel and interference. It is clarified that the network cannot determine the CSI expiration time based on the historic CSI report since the network does not know the exact channel and interference information. Can the network determine the CSI expiration time based on the UL measurement, e.g., SRS measurement, especially for TDD? In this case, the network knows the raw measurement results.  [vivo]:  [Intel] What is the criterion/criteria for “expiration”? |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No evaluation results provided  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Samsung] For TDD bands, channel prediction can be supported by gNB implementation using SRS.  [QC] gNB estimation based on SRS has a lot drawbacks:   1. To use SRS for Doppler tracking, we need something similar to TRS with multiple “looks” in time domain (e.g. 4 symbol gap or repetition across two slots). This can't be made as it requires 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. 2. UL Tx power is much smaller than gNB DL power. So SRS estimation quality is poor for gNB. (UL link budget is worse than DL). 3. Nokia paper in HST [R1-2101009] confirmed that that gNB’s capability to estimate Doppler from SRS is limited.   [Ericsson] If CSI expiration is a concern, the gNB can schedule periodic or semi-persistent CSI report. Then gNB can get a sense of how fast CSI expires.  [HW/HiSi]: HW/HiSi]: If the main purpose of this function is that the gNB shall get assisting information how to set CSI feedback periodicity, then this should already be possible in Rel-16. A short periodicity can be set in the beginning and then can be adjusted (if needed).  [QC] To Ericsson/HW/HISI, deriving CSI expiration from periodic S/SP CSI does work well. It only works in one direction (adjust from small periodicity to larger periodicity). But it does not work in the other direction (adjust from larger to small direction). Let’s consider the following example. Yes, gNB begin with a small periodicity of 1 slot, then derive coherence of the CSI reports, then adjust to use larger periodicity of 40 slots. After a while, the UE switch to high mobility (e.g., get on a bus/car/high-speed-train). How can BS know 40 slots periodicity does not work now and it need to switch to smaller periodicity? CSI expiration time can solve this issue. One might say gNB can figure it out the speed change based on SRS – please see my answers in “Existing R16 solution available”, which list the drawbacks of using SRS. Besides, SRS based solution cannot track interference variations, while the CSI expiration report can take it into consideration.  In summary, it is much better to let UE estimate and report CSI coherence time or CSI expiration time, rather than let BS estimate it. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] medium. UE need to derive expiration time.  [Ericsson] Similar to that of 1-2 |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Samsung] How to specify is unclear  [QC] low spec impact. UE estimate CSI expiration time based on UE implementation. This part does not need to be specified. What needs to be specified is a mapping table between a X bits value and a time (which can be in terms of slots). So the spec impact is low.  [Ericsson] For this feature to meaningful/useful, one or more criteria that CSI is considered expired need to be specified. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Samsung] Testability is unclear  [QC] A test case can be defined with channels with different coherence time. Test equipment then check the value of reported expiration time. And the reported value need to satisfy certain error tolerance level.  [Ericsson] Testability is unclear. As described in [21], the main cause of CSI expiration is interference. Test with different coherence time is inadequate. Also, if CSI expiration time is up to UE implementation as described above, it’s difficult to test that different UE makes correct selection of CSI expiration time or not.  [QC2] To Ericsson: Besides the test related to channel coherence time (see previous input form QC), for the test related to interference, test equipment can add busty periodic interference, then check if the reported CSI expiration time report = interference periodicity with certain error tolerance level. Why it is not testable for interference variation? |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] We will provide more details in next meeting  [Ericsson] Not mature. High level concept description only. No simulation results. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] YES. Without this feedback, gNB does not know how to set/adjust CSI feedback periodicity. For eMBB service, gNB may be able to slowly fine-tuning the periodicity to correct value. But for URLLC, due to fast channel/interference variation, the slow fine-turning does not work. UE feedback could help gNB in this scenario.  [Ericsson] No |

## B.1.11 Case 1-11: Partial information update

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| **Partial information update [5][8][10]** | |
| New report quantity | CQI updated more frequently than RI/PMI |
| Target/benefit | Reduce CSI processing requirement  Scheduler gets CSI closer to actual CSI for the PDSCH scheduling instance  Allows better tracking of channel/interference |
| Additional clarifications/details | [Samsung]: Difference between this and “CSI/SINR statistics”?  [Moderator]: Difference with “CSI/SINR statistics” is that there is no reporting of CQI for every CSI-IM instance for CSI/SINR statistics.  [Nokia]: Is this frequent CQI reporting always assuming the same CSI reference resource or configured to assume a TBS and BLER target different from legacy CQI reporting?  [HW/HiSi] Both is fine.  [Sony] Why configure UE to report RI/PMI if the gNB wants only frequent CQI updates? RI/PMI is for MIMO and are we expecting URLLC to use MIMO?  [ZTE] In our under standing, the benefit is the CSI processing time can be reduced such that the reported CSI can track the interference more accurately. So more appropriate value for the reduced CSI processing time is needed for the simulation.  [vivo] UE reporting CQI by measuring channel and/or interference is supported in LTE. It is beneficial for reduction of CSI measurement/reporting overhead and complexity, thus also potentially reducing CSI computation time.  [Intel] In our understanding, the main benefit could be OH reduction in UCI since the processing time does not provide meaningful gains in URLLC scenarios. In addition, the partial information update is not only about more frequent CQI update than RI/PMI. It could be also the conditional update of any information. |
| **Evaluation results** | |
| Vivo [8]  AR/VR | Full CSI every 40 ms, update CQI only based on IMR every 10 ms:  71% satisfied UEs [67%, period 40 ms]/[98%, period 10 ms]  56% RU [77%, period 40 ms]/[48%, period 10 ms]  Full CSI every 40 ms, update CQI based on CSI-RS and IMR every 10 ms:  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 |
| Huawei [5]  Factory (non-baseline) | Update CQI every 1 ms: 100 supported UEs [70]  Baseline uses full CSI recalculation every 3 ms |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] Some evaluation results are shown  [Company2] Views  [HW/HiSi]: Yes |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No  [Company2] Views  [HW/HiSi]: No, not possible for the UE implementation. In Rel-16 also RI and PMI have to be calculated which is too complex |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views  [HW/HiSi]: low |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views  [HW/HiSi]: low |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] Yes  [Company2] Views  [HW/HiSi]: yes |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] It’s a simple scheme and can be considered mature.  [Company2] Views  [HW/HiSi]: Simple and mature |
| Other | [Samsung] LTE operated in similar manner, this was changed in NR to avoid error propagation issues (when CRC protection is not possible) |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] Yes  [OPPO] Yes  [Ericsson] As explained by moderator, this scheme is closely related to 1-1. We are OK to consider this a special case of 1-1, i.e. if there is only one CSI sample between reports.  [HW/HiSi]: Yes |

## B.2.1 Case 2-1: Decoding margin

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| **Decoding margin [6][12]** | |
| New report quantity | Indication of whether decoded PDSCH pass (fail) with high margin or low margin.  May be reported for each occasion or aggregated for multiple occasions (“slow”) |
| Target/benefit | Successful PDSCH: Reduce BLER of 1st transmission (assists OLLA)  Failed PDSCH: Scheduler knows appropriate parameter (MCS) for retransmission |
| Additional clarifications/details | [Qualcomm]: What decoding information is used to derive the report quantity? How is the report quantity derived? Does the derivation method uniformly work for all modulation orders? How to quantize the report quantity?  [Samsung]: UE procedure to obtain the metrics needs to be described together with the quantization levels (e.g. corresponding to steps of 1 dB, or 2 dB, …, or the MCS equivalent steps). This is important because the whole BLER curve (e.g. between a hard ACK at 10-5 and a soft NACK at BLER=10-1, is only ~5 dB). If there is to be any robustness to interference variations, only one quantization level seems possible. Whether and how information from multiple decoding results is averaged/combined into a single report needs to be described. Further, the gNB can also perform such “deltas” in link adaptation and obtain new OLLA statistics. Need to define gNB action.  [Nokia] Need clarification on how thresholds depend on TBS and MCS (ref R1-2100269 observation 5). Need clarification on how thresholds depend on channel’s fading profile (SINR-distribution in f-domain). How does OLLA converge to different BLERtargets [say 1e-7, 1e-5, 1e-3] with this approach?  [OPPO]  Q1: LDPC decoding implementation is up to vendors. How to make the implementation transparent to the specification of the report (including metric, the way to derive the metric) ?  Q2: The basic target is to apply the report of past decoding margin to the scheduler of future TB. Then how to apply the decoding margin of a codeword of length L1 to the future scheduling (including OLLA) of a code word of length L2? People may argue this can be gNB implementation issue, but it may need some proof to show feasibility.  Q3: Similar to Q2, how to apply the decoding margin of a codeword that was successfully decoded upon the 2nd re-transmission to a future scheduling (including OLLA) of a codeword that gNB wishes to make it success on the initial-Tx? Should this decoding margin also include the number of HARQ transmissions received on the UE side?  [HW/HiSi]: As it also already has been pointed out by other companies, OLLA schemes alone do not seem to give a performance gain. Therefore, if OLLA is evaluated, it should be evaluated under the assumption of accurate or enhanced CSI reports. OLLA schemes only provide CSI information about the scheduled PRBs, whereas partial CQI update can give fast feedback about the entire band and help the scheduler better to make the resource allocation.  [Sony] The aim of soft HARQ-ACK is to make OLLA faster. In eMBB with 10% BLER, the OLLA needs to collect 10 HARQ-ACKs to decide whether to raise or drop MCS. In URLLC with BLER of 10-5 or 10-6, the same OLLA would need 100,000 to 1 million HARQ-ACKs to make the same decision. By allow gNB to adapt the MCS faster would offer gain to the system.  [vivo]: LDPC decoding is implementation related. It is hard to specify the same number of decoding margin for different vendor. Then how the decoding margin is quantified to CQI?  [Intel] How this could be tested and specified in terms of UE behavior? Any example of how this information can be applied in the scheduler is also useful. |
| **Evaluation results** | |
| InterDigital [12]  AR/VR | Soft-ACK (slow): 93.8% satisfied UEs [85.7%], 7.8 PRBs RU [6.7] |
| InterDigital [12]  Factory | Soft-ACK (slow): 100% satisfied UEs [53.3%], 2.4 PRBs RU [1.6] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] Yes, simulation results have been provided in last two meetings.  [Company2] Views  [HW/HiSi]: The results should be evaluated based on accurate CSI information to judge whether the results are meaningful or not |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Ericsson] No  [Company2] Views |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] Low. The UE obtains high vs low margin info by extracting a complementary output from the existing PDSCH decoding procedure.  [Company2] Views |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Ericsson] Low. One extra bit is added in HARQ-ACK feedback.  [Company2] Views |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Ericsson] Yes. The test equipment can test the reported values vs resulting BLER for various conditions.  [Company2] Views |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] The concept is straightforward. The part to be discussed is how to define low margin vs high margin.  [Company2] Views |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Nokia] Yes  [Ericsson] Yes  [HW/HiSi] Not convinced yet. If this is studied further, it should at least also be compared with methods from case 1 (e.g. partial CQI update). |

## B.2.2 Case 2-2: Block error probability

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| **Block error probability [9][13]** | |
| New report quantity | Indication of (log) of estimated block error probability (BLEP) of PDSCH, or delta from a reference (log) BLEP |
| Target/benefit | Successful PDSCH: Reduce BLER of 1st transmission (assists OLLA)  Failed PDSCH: Scheduler knows appropriate parameter (MCS) for retransmission |
| Additional clarifications/details | [Qualcomm]: What decoding information is used to derive the report quantity? How is the report quantity derived? Does the derivation method uniformly work for all modulation orders? How to quantize the report quantity?  [Samsung]: UE procedure to obtain the metrics needs to be described together with the quantization levels (e.g. corresponding to steps of 1 dB, or 2 dB, …, or the MCS equivalent steps). This is important because the whole BLER curve (e.g. between a hard ACK at 10-5 and a soft NACK at BLER=10-1, is only ~5 dB). If there is to be any robustness to interference variations, only one quantization level seems possible. Whether and how information from multiple decoding results is averaged/combined into a single report needs to be described. Further, the gNB can also perform such “deltas” in link adaptation and obtain new OLLA statistics. Need to define gNB action.  [Nokia] See “Implementation complexity”.  [Ericsson] How are the reports generated by the UE? Has this been implemented in detail in the simulations?  [HW/HiSi]: It seems similar in the purpose as 2.1 but defining the BLEP quantity is maybe more complicated than the decoding margin?  [vivo]: Mutual information and look-up table is implementation related? We also concern how to use the uniform design for different vendor.  [Intel] How to derive adjustments for OLLA for sub-bands not used for PDSCH? |
| **Evaluation results** | |
| InterDigital [12]  AR/VR | 90.9% satisfied UEs [85.7%], 7.1 PRBs RU [6.7] |
| InterDigital [12]  Factory | 96.1% satisfied UEs [53.3%], 2.2 PRBs RU [1.6] |
| Nokia [13]  AR/VR | EP only: 5 ms 99.9999%-pct latency [2 ms], 20% RU [3%]  EP + mean + stdev SINR: 1 ms 99.9999%-pct latency [2 ms], 6% RU [3%] |
| Nokia [13]  Factory | EP only: ~1 ms 99.999%-pct latency [1 ms]  EP + mean + stdev SINR: ~1 ms 99.999%-pct latency [1 ms] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Company1] Views  [Nokia] Results show that (a) desired performance level can be achieved with (b) different CQI/MCS-selection schemes (c) in different scenarios. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Nokia] No. Different companies have indicated their agreement that HARQ-ACK/NACK based OLLA is not feasible with low BLERtargets / URLLC – OLLA does not converge due to the absence of NACKs.  [Ericsson] No |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Company1] Views  [Nokia] Medium complexity.   1. Derive mutual information from post-combined SINR or app LLR, i.e: MI=f(LLR) or MI=f(SINR(RE(k)))   where k goes through REs occupied by the TB, and   1. BLEP=f(MI). 2. Report quantity: round( -log10( BLEP ))   When MI is computed from SINR samples, then mean MI per bit (if used) depends on the modulation order (see ref [9] given in R1-2100835).  For report quantity quantization, we think 3 bits can be mapped to 1e-1, 1e-2, …,1e-8.  Treatment of HARQ-codebook changes and multiple decoding results is to be defined.  [Ericsson] High impact to UE implementation |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Nokia] Medium impact due to new report quantity.  [Ericsson] High impact. In addition to the new BLER report, it needs to be specified all other configuration information that the BLER is estimated on, for example, TB size, PRB location, MCS, MIMO scheme, DMRS, etc. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Nokia] At least higher BLERs/EPs can be tested quickly. For lower BLERs a relative test could be perhaps considered i.e. make sure that UE reports monotonically decreasing BLEP when channel conditions improve.  [Ericsson] Higher BLER values are testable. BLER values < 1e-5 is difficult. |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Nokia] UE side is vendor/implementation specific (may depend on receiver/decoder architecture).  [Ericsson] Mature level is low/medium |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Nokia] Yes.  [Ericsson] No. On the other hand, we are fine to consider 2-2 as a variant of 2-1. |

## B.2.3 Case 2-3: (Delta) CQI/MCS/SINR

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| **(Delta) CQI/MCS/SINR [3][4][7][21]** | |
| New report quantity | Indication of transmission parameter (in units of CQI/MCS/SINR) that indicates the difference between the actual MCS/SINR for the PDSCH and the required MCS/SINR to achieve a specific BLER target |
| Target/benefit | Successful PDSCH: Reduce BLER of 1st transmission (assists OLLA)  Failed PDSCH: Scheduler knows appropriate parameter (MCS) for retransmission |
| Additional clarifications/details | [Qualcomm]: The measurement source is PDSCH decoding LLRs. We will provide details in next meeting.  [vivo]: What measurement resource is used?  [Samsung]: UE procedure to obtain the metrics needs to be described together with the quantization levels (e.g. corresponding to steps of 1 dB, or 2 dB, …, or the MCS equivalent steps). This is important because the whole BLER curve (e.g. between a hard ACK at 10-5 and a soft NACK at BLER=10-1, is only ~5 dB). If there is to be any robustness to interference variations, only one quantization level seems possible. Whether and how information from multiple decoding results is averaged/combined into a single report needs to be described. Further, the gNB can also perform such “deltas” in link adaptation and obtain new OLLA statistics. Need to define gNB action (delta\_MCS seems well-defined).  [Nokia]  What is the reference for providing delta CQI? CQI is associated with a CSI-report, not with PDSCH scheduling.  For Delta MCS, we assume that scheduled PDSCH MCS may be used as the reference MCS? However, the UE does not know the BLER target planned for the TB scheduling. What is the assumption of the UE ?  For SINR, similar comments as above. Is this SINR pre-decoding PDSCH SINR or something else?  For all the schemes, how is OLLA adjusted when BLERtargets are specific to each TB? (e.g. different 1st transmissions have BLERtarget 1e-1, 1e-3, 1e-5, 1e-3,…)  [OPPO]: The measurement resource is PDSCH.  [HW/HiSi]: Oppo is saying the PDSCH is the measurement resource. Is this also the view from the other proponents?  [Sony] Delta CQI/SNIR/MCS is similar to Soft-HARQ-ACK shcemes (consisting of Soft ACK and Soft NACK). The aim of this is to let gNB know how far a decoding is from the target. It will be good to lump them all into one scheme.  [QC2] Similar view as Sony, Case 2-1, 2-2, 2-3 are all belong to the same family which is the soft ACK/NACK feedback. The only difference is the form of feedback details such as whether feedback decode margin or BLER or (delta) CQI/MCS/SINR. It is better to lump Case 2-1, 2-2, 2-3 into a single scheme.  [vivo] There is no much difference among Case 2-1/2-2/2-3, as Sony and QC also commented. These cases are reporting some information in different forms according to the PDSCH decoding processing and results. One question is that the reported information is only based on the decoding on the scheduled PRBs in the previous transmission and the same precoder needs to be assumed. How to make use of the reported information to adjust the scheduling and MCS selection for the next transmission (new transmission or retransmission), if different time/frequency resources and length would be used.  [Intel] how this is different from measuring full/conventional CSI? |
| **Evaluation results** | |
| ZTE [3]  AR/VR | Delta SINR (ACK): 61% satisfied UEs [50%], 2.3% RU [1.9%]  Delta SINR (NACK): 94% satisfied Ues [50%], 33% RU [1.9%]  Delta MCS (NACK): 60% satisfied Ues [50%], 1.9% RU [1.9%] |
| InterDigital [12]  AR/VR | Delta SINR (ACK): 99.6% satisfied Ues [85.7%], 16.2 PRBs RU [6.7] |
| InterDigital [12]  Factory | Delta SINR (ACK): 100% satisfied Ues [53.3%], 3.0 PRBs RU [1.6] |
| Intel [10]  AR/VR | CSI: 99.35% [99.25%] Ues for 99.99% reliability |
| Qualcomm [21]  AR/VR mixed  (20 URLLC UEs) | CQI/MCS: 100% satisfied Ues [100%], 3471 RBs for 2nd Tx [5255] |
| Qualcomm [21]  AR/VR mixed  (100 URLLC UEs) | CQI/MCS: 100% satisfied Ues [100%], 5878 RBs for 2nd Tx [7545] |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Company1] Views  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [QC] NO. R16 cannot provide delta MCS feedback to improve OLLA at gNB.  [OPPO] No.  [Ericsson] No |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] UE need to implement LLR -> (delta) MCS mapping  [Ericsson] Low impact |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] low. Only a table to capture a X bit -> (delta) MCS is needed.  [Ericsson] Low spec impact |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Samsung] delta\_MCS is easiest to test among this (and decoding margin, EP)  [QC] agree with Samsung (delta) MCS is easiest to test  [OPPO] Similar view with Samsung and QC  [Ericsson] yes |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] The concept is fairly straight forward, and can be considered mature.  [Company2] Views |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] Yes  [QC] YES  [OPPO] Yes  [Ericsson] Yes. Also, Case 2-3 can be combined with 2-1 to study. If the delta value in Case 2-3 is represented by 1 bit, then it’s the same as 2-1. |

## B.2.4 Case 2-4: HARQ redundancy version sequence

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| **HARQ redundancy version sequence [20]** | |
| New report quantity | Indication of recommended HARQ redundancy version sequence |
| Target/benefit | Scheduler knows the best HARQ redundancy version sequence to use |
| Additional clarifications/details | [Qualcomm]: What decoding information is used to derive the report quantity? How is the report quantity derived? Does the derivation method uniformly work for all modulation orders? How to quantize the report quantity?  [Nokia] :  What are the different redundancy version sequences reported, and how shall the gNB use this for initial transmission and re-transmissions?  In Rel-15, there were good investigations on which RV sequences are the best, and it is understood the gNB knows the best sequence to be used. Why is this not a valid assumption and UE feedback is needed? It would be good to provide details on the fundamental issue with RV selection.  Besides, how this helps OLLA for initial transmission?  [ZTE] How does the UE know which RV should be used for retransmission, especially in the SLS? How to reflect the RV impact in the SLS?  [Intel] in low code rates, there is smaller difference in RV performance. It seems the technique may only be useful in some limited cases, if any. |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Samsung] We do not think there is any benefit for the UE to indicate preferred RV sequence (because at low BLERs or for small TBs, the RV sequence has negligible impact).  [Ericsson] No simulation results. We do not expect meaningful gains from RV indication by UE. Case 3-4 is motivated by that UE can request RV0 retransmission when much additional info is needed, and RV1 when only small amount is needed. But if only small amount of info is needed, then likely any RV would work. |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Apple] No  [Ericsson] The target benefit itself is not proven to exist |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Apple] UE makes request and gNB honors the request.  [Ericsson] Low |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Ericsson] Low  [Company2] Views |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Apple] testability of the scheme is guaranteed  [Ericsson] Not appear to be testable. What’s the criteria that UE should recommend one RV sequence and not another RV sequence? |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [Ericsson] Low  [Company2] Views |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [Apple] Yes  [Ericsson] No |

## B.2.5 Case 2-5: Reason for NACK

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| **Reason for NACK [14][21]** | |
| New report quantity | Indication of whether NACK is due to radio propagation or strong spike in interference |
| Target/benefit | Scheduler knows whether to switch beam or change other transmission parameters. Scheduler can also decide on the SNR step size used in an OLLA, e.g. if a NACK is caused by spike in interference, then a smaller reduction in SNR step size is used compared to when the NACK is caused by poor radio condition. |
| Additional clarifications/details | [QC] UE via a combination of measurements on CSI RS and DMRS to identify PDSCH decoding failure is due to which of the following 1) Beam blocking; 2) Other cell interference; 3)Frequency selective fading; 4) coverage hole. UE then report the reason (with recommended operations) to base station to help base station take actions accordingly.  [Nokia]: Is this send only with NACK? If the BLER target is low, this does not help OLLA.  How exactly would UE distinguish between the suggested failure reasons? Is there any other enhancements are required to detect this?  What would it report if multiple reasons are present simultaneously?  How the gNB PUCCH resource allocation and UCI decoding should be?  What would the corrective actions be in each case or with a combination of reasons? Is it only an OLLA step size adjustment? What are the OLLA step size adjustments for different reports?  [HW/HiSi] Similar comment as Nokia. NACK is occurring very seldom in URLLC. It seems not justified to spend efforts on enhancements that only work for NACK.  [Sony] Is should belong to Soft-NACK. A NACK due to an interference spike and one due to poor radio condition should be treated differently. In the conventional OLLA, when a NACK occurs, the OLLA step size drops significantly and for URLLC case, it would take 1 million ACKs before it is allowed to move to a higher MCS (or back to original MCS). If it is just an interference spike, we do not need 1 million ACKs for OLLA to realised that the MCS can be maintained. If it is a radio condition then it can lower the MCS. This works the same as soft ACK. Furthermore if Soft-ACK is implemented, the HARQ-ACK feedback would require 2 bits anyhow, and we would have sufficient bits for soft-NACK.  [ZTE] How does the UE know the reason for the PDSCH decoding failure, e.g., beam switching or the lower SINR? What’s the corresponding network behavior if the UE reports the reason of beam switching? |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No simulation results  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [QC] No  [Ericsson] No |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [Ericsson] High impact to UE. UE needs to define new procedure to differentiate 4 reasons why PDSCH decoding failed  [Sony] UE can determine whether there is a sudden rise in interference. The detection mechanism isn’t complex. |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [Samsung] Practically impossible to define.  [Ericsson] High impact to spec. What’s the criteria to differentiate the 4 reasons PDSCH decoding failed? 1) Beam blocking; 2) Other cell interference; 3)Frequency selective fading; 4) coverage hole.  [Sony] We believe only 2 reasons are sufficient. Sudden rise in interference or no sudden rise in interference causing the NACK. That’s it. |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [Samsung] Practically impossible to test.  [Ericsson] Not testable  [Sony] Why is this impossible to test? A test system can easily increase/decrease interference. |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] We will provide details in next meeting  [Ericsson] Not mature. High level concept only. Many details are missing |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] No  [QC] Yes  [Ericsson] No  [Sony] If we accept Soft-ACK, we should also consider Soft-NACK. Otherwise we should not do any Soft- HARQ-ACK scheme. |

## B.2.6 Case 2-6: Number of NACK values

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| **Number of NACK values [19]** | |
| New report quantity | Indication of the number of NACK values among NACK/DTX values |
| Target/benefit | Scheduler knows whether to adapt PDSCH (in OLLA) or PDCCH. Enables conventional OLLA. |
| Additional clarifications/details | [Nokia]: The main issue as highlighted before, how come the reliability targets are met when the solution assumes NACKs to drive OLLA. Is not that the fundamental issue we discuss/need enhancements?  Why is it difficult for gNB to track the number of NACKs reported by the UE anyways?  [HW/HiSi]: Could it be clarified: Is this motivation to distinguish if the reason for a reported NACK in the codebook is due to a wrongly decoded PDSCH or due to a missed PDCCH? If it is the former, conventional OLLA will be used, otherwise, no OLLA is performed?  [ZTE] It seems the purpose is the network can distinguish the DTX and NACK. It would be better to clarify the problem if the network assumes all the NACKs are PDSCH decoding failure first.  For PDSCH, even though it may lead to the scheduling is a bit more preservative, the network can make further adjustment to obtain the appropriate MCS according to the OLLA based on the subsequent ACKs.  For PDCCH, the network scheduling is usually very conservative. The probability of DTX is very low. Even though the network can know the DRX, it is difficult for the network to make some adjustment because the granularity for the PDCCH is large, e.g., aggregation level 8 to aggregation 16. In most case, the AL adjustment is based on the report. In addition, it has been identified that the PDCCH reliability is not an issue in Rel-16.  [Intel] Would be good to understand whether DTX vs NACK confusion is typical in URLLC scenarios. Otherwise the effort vs potential usefulness is uncertain. |
| **Evaluation results** | |
| (Not available) |  |
| **Company views for each criterion (not necessarily by order of importance)** | |
| Performance | *Do evaluation results and metrics show a meaningful benefit for an agreed scenario?*  *Does the gain justify the cost in terms of resource utilization, UL overhead, implementation/spec impact?*  [Ericsson] No simulation results. Also, we are not convinced of the benefit. For URLLC traffic, there is (or should be) very few NACK, e.g., 10-4. In such case, the UE reports zero NACK almost all the time. The scheduler does not really get help to select MCS better.  [Company2] Views |
| Existing R16 solution available? | *Is it possible to achieve the targeted benefit by UE/gNB implementation in R16?*  [Samsung] No. Unless number of HARQ-ACK bits is only 1-2, reported state is NACK/DTX.  [QC] No.  [Ericsson] No. On the other hand, we are not convinced of the target benefit. |
| Implementation complexity | *What is the impact on UE/gNB implementation complexity? (e.g. low/medium/high, please explain)*  [QC] low. UE just count # true NACKs and feedback a number.  [Ericsson] Low impact |
| Specification impact | *What is the impact on specifications? (e.g. low/medium/high, please explain)*  [QC] low. Just append # true NACK at the end of the HARQ-ACK codebook  [Ericsson] Low impact |
| Testability/inter-operability | *Is it possible to test the new report such that inter-operability is achieved?*  [QC] YES.  [Ericsson] Yes |
| Maturity | *How mature is the proposal from design perspective? Are there many options/sub-options to investigate down the road?*  [QC] relatively simply idea. Mature enough.  [Ericsson] The concept is simple. However, there is no proof that this gives any performance benefit. |
| Other |  |
| Continue study? | *Do you think RAN1 should continue study of this scheme for R17 IIoT/URLLC?*  [Samsung] Yes  [Ericsson] No |