**3GPP TSG RAN WG1 #105-e R1-21xxxxx**

**e-Meeting, May 10th – 27th, 2021**

**Agenda Item: 8.3.1.2**

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

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

**Document for: Discussion and Decision**

# Introduction

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

|  |
| --- |
| 1. Study, identify and specify if needed, required Physical Layer feedback enhancements for meeting URLLC requirements covering
	* + UE feedback enhancements for HARQ-ACK [RAN1]
		+ CSI feedback enhancements to allow for more accurate MCS selection [RAN1]

Note: DMRS-based CSI feedback is not in scope of this WI  |

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

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

In RAN1#104-e, a detailed set of Case 1 and Case 2 schemes was identified for continued evaluation ([23], Appendix B) and additional discussions took place after RAN1#104-e to better understand each scheme and associated aspects such as implementation complexity, specification impact and testability [24].

In RAN1#104b-e, RAN1 agreed to focus study for Case 1 on reporting of new metric determined based on network configured channel and interference measurement interval, increasing granularity of subband CQI and updating only CQI in a report. For new reporting Case 2, RAN1 agreed to focus on reporting of delta-CQI/MCS.

Here is the color code used in this summary:

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

# Collection of agreements/conclusion in RAN1 #104b-e

To be captured once agreement is made during this meeting

# Proposals for 1st GTW

The following were presented in 1st GTW session:

**FL proposal 8.1-1**: **Support new metric based on network configured channel and interference measurement interval, where new metric is a minimum CQI value at least in frequency domain (“worst-M CQI”).**

* **FFS: Definition with multiple channel and interference measurement instances within time interval**

**FL proposal 8.1-2: If increasing granularity of subband CQI is supported, the maximum number of bits per subband CQI is 3 bits.**

**FL proposal 8.1-3**: **If reporting with CQI-only update is supported:**

* **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
	+ **Note: this does not preclude use of new report based on configured channel and interference measurement, if supported.**
* **Support shorter CSI computation time compared to R16.**

**FL proposal 9.1-1**: **Support reporting of delta-MCS for a TB received with MCS index IMCS:**

* **delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
* **FFS: How to determine BLER target.**

**FL proposal 9.1-2**: **For reporting of delta-MCS, select between the two following options for the resource:**

* **Option 1: delta-MCS is reported as part of an extended HARQ-ACK codebook**
* **Option 2: delta-MCS is reported as a CSI report separate from HARQ-ACK codebook**
	+ **FFS: Type of resource (e.g. PUCCH or higher layers)**

# Proposals for 1st check point

TBD

# Proposals for 2nd check point

TBD

# Proposals for 3rd check point

TD

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

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

## Summary of issues for Topic #1

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

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

* Yes: Huawei [4], ZTE [5], vivo [8], NTT DOCOMO [20]
	+ The development of new feedback reporting schemes (especially case 2 schemes) is impacted by whether aperiodic CSI can be reported on PUCCH or not [4].
	+ Better performance than A-CSI on PUSCH and P/SP-CSI on PUCCH due to more flexible feedback [5],
	+ Trigger reporting based on traffic needs for sporadic traffic [20]
	+ No latency increase for CSI reporting (e.g. due to waiting for UL grant for triggering) [4]
	+ Less uplink overhead than A-CSI on PUSCH in DL-heavy scenarios, or SP-CSI/P-CSI with low periodicity [20]
	+ Transmission of single PDCCH transmission instead of two PDCCH with A-CSI on PUSCH [4][5][8]:
		- Less interference and resource utilization than A-CSI on PUSCH
		- Avoid blocking/increased latency from exceeding blind decoding limit per span or lack of coreset capacity
		- Better spectral efficiency
		- Avoid reduction of reliability due to CCE channel estimation limit
		- Avoid reduction of reliability from having to successfully receive two PDCCHs
* Some concerns: Lenovo [22]
	+ Need to decide whether PUCCH resource is same or different than HARQ-ACK [22]
* No: Mediatek [21], LG [17]
	+ P/SP-CSI reporting more suitable for factory scenario with periodic traffic [21]
	+ For factory scenario, coherence time is larger than latency requirement, therefore no need to update the CSI report for re-transmission [21]
	+ P/SP-CSI reporting every 10 ms sufficient for AR/VR scenario with 22 ms coherence time [21]
	+ No clear enhancement compared to A-CSI on PUSCH [21]
	+ If CSI and HARQ-ACK are combined in same resource, need to delay HARQ-ACK compared to processing capability 2 and increased probability of error with larger payload [21]
	+ e.g. complicated timeline [19]
	+ wasting resource since no retransmission is needed ~99% of the time [21]
	+ Resources for CSI in the UL may be limited by other URLLC transmissions [19]

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

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

* Yes: Huawei [4], ZTE [5], Qualcomm [10]
	+ No extra demands on PDCCH blind decoding
	+ Avoid reduction of reliability due to CCE channel estimation limit
	+ Good performance in terms of percentage of satisfied UEs [5]
	+ Avoids excessive overhead of low CSI-RS periodicity/CSI report [10]
	+ Can be used with semi-persistently scheduled PDSCH [10]
* No: Mediatek [21]
	+ May increase power consumption by requiring unnecessary A-CSI computation 99% of the time [21]

Some contributions [3][4][15] identify that supporting new reporting Case 2 may require introduction of aperiodic triggering from DL DCI if the report is not transmitted as an extension of the HARQ-ACK codebook.

Two contributions [5][21] discuss potential support of triggering a A-CSI report by group DCI. However, neither contributions support this option. The main reason is the inefficient use of group DCI resources since packet arrivals are not synchronous between UEs.

Two contributions [5][20] propose to support priority handling for A-CSI on PUCCH, if supported.

One company [10] proposed to support UE requesting CSI measurement to update CSI (when UE autonomously updates its Rx beam).

One company [20] proposes to support A-CSI on PUCCH multiplexed on PUSCH repetition type B.

**Observations on new triggering methods.**

Compared to RAN1#104b-e, there does not seem to be any change of view or any additional data. Several companies do not discuss the topic any more in their contribution submitted to RAN1#105. For this reason, it is suggested to focus on Topic #2 and Topic #3 in RAN1#105.

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

TBD

# Topic #2: New reporting (Case 1)

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

## Summary of issues for Topic #2

At RAN1#105, it was agreed to focus study of Case 1 new reporting to the following schemes:

* Reporting of new metric determined based on network configured channel and interference measurement interval. The new metric is to be downselected in RAN1#105-e.
	+ The new metric is to enable the scheduler to pick a MCS based on the tail of distribution of possible channel quality experienced at the scheduling time.
* Increasing granularity of subband CQI (e.g. 3-bits differential subband CQI or 4-bits full subband CQI).
	+ The increased granularity is to avoid inaccurate subband CQI report when a subband CQI is much worse than wideband CQI
* Updating only CQI in a report, where CQI is conditioned on a previous instance in which RI/PMI/(CRI) is updated.
	+ The update of CQI only may enable reduction of delay between CQI measurement and reporting

In following sections, performance results and views on each scheme are presented.

## Reporting of new metric

### Statistical CSI/SINR (Case 1-1)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-1Mean and stdev SINR(K=5, L = 100) | AR/VR | 85% satisfied UEs [48%]26% RU [71%] |
| Futurewei [2] | Case 1-1Mean and stdev SINR(K=10, L = 200) | AR/VR | 80% satisfied UEs [48%]31% RU [71%] |
| ZTE [5] | Case 1-1Mean + stdev CQI | AR/VR | 31% satisfied UEs [50%] 2.9% RU [1.9%](gNB sets MCS based on MeanCQI – StdevCQI) |
| InterDigital [18] | Case 1-1Mean+stdev SINR | AR/VR(20 UEs /cell) | 93% satisfied UEs [85%] 7.6 RU [6.5 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 1-1Mean+stdev SINR | Factory(20 UEs /cell) | 96% satisfied UEs [98%] 5.9 RU [1.3 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 1-1Mean+stdev SINR | Factory(40 UEs /cell) | 64% satisfied UEs [9%] 6.4 RU [3.4 RU]Report periodicity 20 ms |
| Nokia [19] | Case 1-1Mean + stdev SINR | Factory | 1 ms 99.9999%-pct latency [2 ms]5% RU [3%] |
| Ericsson [26] | Case 1-1Mean and stdev CQI (wideband) | AR/VR (mixed traffic) | 97.5% satisfied UEs [78.5%]76% median RU [77%]Baseline uses fixed backoff of 20 dB |
| Ericsson [26] | Case 1-1Mean and stdev CQI (subband) | AR/VR(mixed traffic) | 97.2% satisfied UEs [78.5%]60% median RU [77%]Baseline uses fixed backoff of 20 dB |
| Intel [12] | Case 1-1Mean+stdev SINR(IMR for actual loading) | Factory | 42% satisfied UEs [42%]6.3% RU [6.3%] |
| Intel [27] | Case 1-1Mean+stdev SINR(IMR for full loading) | Factory | 57% satisfied UEs [37%]30.48% RU [24%] |

Company views

Supportive: Ericsson [3], CMCC [9], Intel [12], Sony [14], Nokia [19] (SINR only), (NTT DoCoMo [20]), Lenovo [22]

* Does not require LA backoff parameter optimization, shows superior performance [3]
* Other evaluations underestimated benefit due to not using mean-SINR, biasing reported mean-SINR, or assuming improper use of the mean/std-SINR reports in scheduling [3]
* Support larger sample of measurements [9]
* More reliable than instantaneous measurement [12]
* Multiple CSI reports do not work on the borders of SINR range of CQI [12]
* Compresses multiple measurements in single report (overhead reduction) [14][20]
* (for SINR) Allow channel characterization and link adaptation for any BLER and TBS (performance uncertainty from different UE implementations smaller than uncertainty from fading profile with CQI) [19]

Concerns: Futurewei [2], Huawei [4], ZTE [5], Spreadtrum [7], CATT [8], Apple [13], Quectel [15], Samsung [16], LG [17], Nokia [19] (CQI only), Qualcomm [10]

* Including signal part in the statistics increases uncertainty with large sampling period if signal part is known from recent CSI report [2] (this assumes that mean SINR is not reported?)
* Prior knowledge of distribution is necessary at gNB side [4]. Unclear if mean and stdev are right quantities for feedback if distribution is unknown [13][16]
* Difficult to define/specify std-CQI/SINR table, high standards effort [4][5][7][16]
* Unclear how to perform testing [8]
* (for SINR): Performance for given SINR is implementation dependent [15][16][17]
* Increased UE complexity to perform filtering [4][15]
* Overhead increase if per-subband statistics need to be reported [16]
* Can provide frequent CQI reports instead [4][16][17]
* (for CQI): report quantity applies only to assumed TBS and target BLER, requires adjustments and may be inaccurate [19]

Aspects to further study:

* Control/configuration of measurement time range or number of measurements for mean/stdev CQI [9]
* Using mean, stdev, min or max [12]
* Whether to report reference CSI reporting to address testability issues [13]
* Time window size, minimum number of CSI samples, whether to exclude outliers, how to quantize and report statistics [22]

### Interference statistics (Case 1-3)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-3stdev of interference(K=5, L=100) | AR/VR | 90% satisfied UEs [48%]24% RU [71%] |
| Futurewei [2] | Case 1-3stdev of interference(K=10, L=200) | AR/VR | 92% satisfied UEs [48%]22% RU [71%] |

Supportive: Futurewei [2], Intel [12]

* No existing R16 solution available to provide gain [2] because of quantization issues with legacy CQI
* Low feedback overhead (e.g. every 100 TTIs) [2]
* Low implementation complexity since interference needs to be measured anyway [2]
* Low specification impact – only need to add new reporting quantity for interference stdev/variance [2]
* Testable with controllable interference source [2]
* Simple, mature concept [2]

Concerns: Ericsson [3], Huawei [4], ZTE [5], Spreadtrum [7], CATT [8], Sony [14], Quectel [15], Samsung [16], Nokia [19], NTT DoCoMo [20], Lenovo [22], Qualcomm [10]

* Assumes certain type of receiver (MRC), does not take into account spatial properties of interference [3][15]. Was discussed and not adopted in eMIMO for this reason [3]
* Prior knowledge of distribution is necessary at gNB side [4][16]
* Required information may vary depending on gNB scheduling algorithm [20]
* Can provide frequent CQI reports instead [4]
* Not self-contained as interference stdev report cannot be used by itself [3], unclear how to combine with other CSI quantities [17]
* Difficult to define/specify [7], higher spec impact than statistical CQI/SINR [4][5][16]
* Unclear how to perform testing [8]
* Need mean value of interference, information is similar to mean+stdev CQI/SINR [14]
* Increased UE complexity to perform filtering [4][15]
* Network can use long-term RSRP and RSSI measurements instead [16]
* Large dynamic range of interference, may not capture deep fade of desired signal [17]
* Benefit over statistical CQI/SINR is not clear [22]

### CSI based on worst IMR occasion (Case 1-5)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-5CSI based on worst IMR occasion | AR/VR | 70% satisfied UEs [48%]38% RU [71%] |
| ZTE [5] | Case 1-5CSI based on worst IMR occasion | AR/VR | 58% satisfied UEs [50%] 2.3% RU [1.9%]  |
| Intel [12] | Case 1-5CSI based on worst IMR occasion(IMR for actual loading) | Factory | ??% satisfied UEs [42%]6.3% RU [6.3%] |
| Intel [12] | Case 1-5CSI based on worst IMR occasion(IMR for full loading) | Factory | 61% satisfied UEs [37%]46% RU [24%] |
| InterDigital [18] | Case 1-5CSI based on worst IMR occasion | AR/VR(20 UEs /cell) | 84% satisfied UEs [85%] 7.1 RU [6.5 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 1-5CSI based on worst IMR occasion | Factory(20 UEs /cell) | 83% satisfied UEs [98%] 2.3 RU [1.3 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 1-5CSI based on worst IMR occasion | Factory(40 UEs /cell) | 14% satisfied UEs [9%] 4.7 RU [3.4 RU]Report periodicity 20 ms |

Supportive: Huawei [4], ZTE [5], Spreadtrum [7], (LG [17]), (InterDigital [18]), Lenovo [22]

* Easy to implement [4], [5]
* Can reflect interference variations in time [5], avoid having to use too low MCS [5]
* Avoids continuous CSI reporting [17]

Concerns: Futurewei [2], Ericsson [3], CATT [8], CMCC [9], Sony [14], Quectel [15], Samsung [16]

* Worst IMR in a recent occasion may not represent worst-case IMR that can happen [2][3][9]
* Unclear benefit compared to subband reporting [8]
* Provides less information than statistical CSI [14]
* Increased UE complexity to perform filtering [15]
* Network can apply a backoff without this measurement [16]
* WB information insufficient, unclear definition of worst occasion for sub-band CQI [17]

Aspects to consider further:

* Definition of worst IMR [4]
* Definition/selection of IMR occasion with multiple configured CSI-RS [4]

### Worst-M CQI (Case 1-6/1-7)

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Futurewei [2] | Case 1-6Worst-M CQI | AR/VR | 76% satisfied UEs [48%]31% RU [71%] |
| Nokia [19] | Case 1-6Worst-2 CQI | Factory | ~1 ms 99.999%-pct latency [2 ms]5% RU [3%] |
| Nokia [28] | Case 1-6Worst-M CQISingle IMR | AR/VR(Mixed traffic) | 77% satisfied UEs [74%, single IMR]Report periodicity 2 ms |
| Nokia [28] | Case 1-6Worst-M CQISingle IMR | AR/VR(Mixed traffic) | 73% satisfied UEs [74%, single IMR]Report periodicity 10 ms |
| Nokia [28] | Case 1-6Worst-M CQIMultiple IMR | AR/VR(Mixed traffic) | 100% satisfied UEs [74%, single IMR]Note: R16 subband CQI + multiple IMR has 100% satisfied UEsReport periodicity 10 ms  |
| InterDigital [18] | Case 1-6Worst-M CQI | AR/VR(20 UEs /cell) | 93% satisfied UEs [88%] 6.8 RU [6.5 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-6Worst-M CQI | Factory(20 UEs /cell) | 100% satisfied UEs [98%] 2.0 RU [1.3 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-6Worst-M CQI | Factory(40 UEs /cell) | 68% satisfied UEs [9%] 4.8 RU [3.4 RU]Report periodicity 2 ms |

Supportive/open: Huawei [4], Qualcomm [10], Quectel [15], LG [17], InterDigital [18], Nokia [19], NTT DoCoMo [20], Lenovo [22]

* Simple extension of R16, low implementation impact [4][15][19][20]
* Reduce overhead and ensure high downlink reliability [10]
* More aligned with current CSI framework compared to other schemes [17]
* Avoids continuous CSI reporting [17]
* Testable [19]
* Can include CSI based on worst IMR occasion if worst IMR occasion is selected for reporting

Concerns: Futurewei [2], Ericsson [3], ZTE [5], Spreadtrum [7], CATT [8], Apple [13], Samsung [16]

* Worst CQI in a recent measurement may not represent worst-case CQI that can happen [2][3]
* Benefit only in Factory scenario for which interference in time is predictable. Does not benefit for AR/VR [3]
* Only provides worst-CQI in frequency [7]
* Only benefit compared to subband reporting is overhead [5][8][16]
* Unclear if stationarity for interference can be assumed. If network coordination makes interference more predictable, reporting can be achieved by reportFreqConfiguration 3040[13]

Aspects to study further:

* Handling of multiple CSI-RS resources [10]
* Whether to report one or subset of worst CQIs [10]
* 4-bits or D-CQI for the worst-case, adding to or replacing existing CQI [19]

## Increasing granularity of subband CQI (Case 1-8)

|  |  |  |  |
| --- | --- | --- | --- |
| Intel [12] | Case 1-84-bits full CQI | FactoryIMR for actual loading | 43%(?) satisfied UEs [42%]6.3% RU [6.3%] |
| Intel [12] | Case 1-84-bits full CQI | FactoryIMR for full loading | 32% satisfied UEs [37%]24% RU [24%] |
| Samsung [16] | Case 1-83-bit Diff-CQI | ??? | 0.2%, 1.9%, 1.0% gain for average/median/5 pctile throughput respectively. |
| Samsung [16] | Case 1-84-bits full CQI | ??? | 0.5%, 0.7%, 15.6% gain for average/median/5 pctile throughput respectively |
| InterDigital [18] | Case 1-83-bits Diff-CQI | AR/VR(20 UEs /cell) | 88% satisfied UEs [88%] 6.5 RU [6.5 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-83-bits Diff-CQI | Factory(20 UEs /cell) | 95% satisfied UEs [98%] 1.3RU [1.3 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-83-bits Diff-CQI | Factory(40 UEs /cell) | 7.8% satisfied UEs [8.8%] 3.3 RU [3.4 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-84-bits full CQI | AR/VR(20 UEs /cell) | 88% satisfied UEs [88%] 6.5 RU [6.5 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-84-bits full CQI | Factory(20 UEs /cell) | 95% satisfied UEs [98%] 1.3 RU [1.3 RU]Report periodicity 2 ms |
| InterDigital [18] | Case 1-84-bits full CQI | Factory(40 UEs /cell) | 8% satisfied UEs [9%] 3.3 RU [3.4 RU]Report periodicity 2 ms |
| Nokia [20] | Case 1-84-bits full CQI | Factory | 1 ms 99.9999%-pct latency [2 ms]6% RU [3%] |
| Mediatek [21] | Case 1-83-bits Diff-CQI | Factory | 0.4% of incorrect MCS [22%]Baseline uses 2-bit D-CQIIncorrect MCS defined as scheduled MCS using scheme minus scheduled MCS using 4-bits SB-CQI |
| Mediatek [21] | Case 1-83-bits Diff-CQI | Factory | 21.2% RU (25.1%) |
| Mediatek [21] | Case 1-84-bits full CQI | Factory | 21.2% RU (25.1%) |

Supportive: Huawei [4], Spreadtrum [7], Sony [14], Samsung [16], NTT DoCoMo [20], Mediatek [21]

* Increases accuracy of the subband report [4][14][20][21]
* Little specification effort [7][20]

Concerns: Ericsson [3], Intel [12], Apple [13], InterDigital [18], Nokia [19]

* Does not help if interference is unpredictable in time [3]
* Increases overhead [19] by up to 43% (3 bits) or 87% (4 bits) [3]
* Gains are not sufficient [12][18]
* Cannot assume stationarity of interference [13]

## Updating CQI-only (Case 1-11)

|  |  |  |  |
| --- | --- | --- | --- |
| Huawei [4] | 0.5 ms delay between CSI meas. and report(for all reports) | Factory12 UEs per cell | 100% satisfied UEs [70%] |
| Huawei [4] | 0.5 ms delay between CSI meas. and report(for all reports) | Factory15 UEs per cell | 69% satisfied UEs [37%] |
| Huawei [4] | 1 ms delay between CSI meas. and report(for all reports) | Factory(non-baseline) | 100 supported UEs for 100% availability [70] |
| Vivo [6] | Case 1-11Full CSI every 20 msUpdate CQI based on CSI-RS and IMR every 5 ms | AR/VR | 89% satis. UEs [83%, baseline1]/[87%, baseline2]57% RU [62%, baseline1]/[57%, baseline2]Baseline 1 uses full CSI recalculation every 20 msBaseline 2 uses full CSI recalculation every 5 ms |
| InterDigital [18] | Case 1-11Full CSI every 20 msUpdate CQI based on IMR every 2 ms | AR/VR(20 UEs /cell) | 85% satis. UEs [85%, baseline1]/[88%, baseline 2]6.9 RU [6.9 RU, baseline1]/[6.5 RU, baseline2]Baseline 1 uses full CSI recalculation every 20 msBaseline 2 uses full CSI recalculation every 2 ms |
| InterDigital [18] | Case 1-11Full CSI every 20 msUpdate CQI based on IMR every 2 ms | Factory(20 UEs /cell) | 97% satis. UEs [98%, baseline1]/[98%, baseline 2]1.3 RU [1.3 RU, baseline1]/[1.3 RU, baseline2]Baseline 1 uses full CSI recalculation every 20 msBaseline 2 uses full CSI recalculation every 2 ms |
| InterDigital [18] | Case 1-11Full CSI every 20 msUpdate CQI based on IMR every 2 ms | Factory(40 UEs /cell) | 9.6% satis. UEs [8.5%, baseline1]/[8.8%, baseline 2]3.4 RU [3.3 RU, baseline1]/[3.4 RU, baseline2]Baseline 1 uses full CSI recalculation every 20 msBaseline 2 uses full CSI recalculation every 2 ms |
| Nokia [28] | Case 1-11Full CSI every 10 msUpdate CQI every 2 ms | AR/VR | 93% satis. UEs [92%, baseline1]/[93%, baseline2]Baseline 1 uses full CSI recalculation every 10 msBaseline 2 uses full CSI recalculation every 2 ms |
| Nokia [28] | Case 1-11Full CSI every 20 msUpdate CQI every 2 ms | AR/VR | 93% satis. UEs [91%, baseline1]/[93%, baseline2]Baseline 1 uses full CSI recalculation every 20 msBaseline 2 uses full CSI recalculation every 2 ms |

Supportive: Huawei [4], Vivo [6], Spreadtrum [7], Oppo [11], NTT DoCoMo [20]

* Requires less computation time and can reduce gap between measurement and scheduling instance [4][5][20]
* Legacy processing delay for subband CQI is too long for URLLC – need delay requirement 1 [4][6]
* Reducing CSI computation improves performance [4][6][7]
* Overhead reduction in UCI (if RI/PMI not reported) [7]
* Spatial related information may not change frequently [11]
* Computation complexity reduced from O(192) to O(1) [11]
* Low implementation and spec impact [20]

Concerns: Ericsson [3], CATT [8], Intel [12], Sony [14], Samsung [16], Nokia [19], Mediatek [21]

* Splitting report across multiple instances risks mis-detection and error propagation [3][16]
* Splitting report across multiple instances violates self-contained principle adopted in NR from R15 and would increase specification complexity (introduce new mode, specify CPU occupancy and CSI timeline) [3]
* Can be achieved by implementation in R16 by utilizing two CSI report configurations and different reporting frequencies [3]
* Can be achieved by implementation in R16 by restricting rank to 1 and obtaining PMI from SRS [16]
* Out-performed by statistical CSI/SINR since it cannot use CSI-IM time occasions occurring before and after a CSI-RS time occasion [3].
* No benefit if CSI processing time cannot be reduced compared to R16 [8][14]
* Does not directly solve problem of more accurate MCS selection [12]
* Possible CSI processing time reduction is limited to 10%-20% [16]
* Performance impact if CRI/PMI/RI actually changes [19]. May need to define conditional CRI/PMI/RI omission rules.
* Degrades performance compared to full CSI updates [21]

Aspects to study further:

* How many symbols can be reduced for CSI processing time [5] and what would the performance gain be
* Definition of “previous instance in which RI/PMI/(CRI) is updated”, same CSI-ReportConfig or linked CSI-ReportConfig [11]
* Potential payload size ambiguity [17]
* How to trigger CQI only update [17]

## Observations for Topic #2

For reporting of new metric to enable more accurate selection, four schemes were studied and analyzed by companies:

**Statistical CQI/SINR** (mean + stdev CQI/SINR): This scheme was evaluated by multiple companies and a significant gain is observed by most. The main benefit of this scheme is that it may provide the network with a good picture of the main characteristics of the CQI distribution (mean and standard deviation), from which the CQI at the tail of the distribution can be estimated. The main concern is the higher complexity (relative to other schemes) for the UE to obtain the quantities. Another concern is the use of CQI versus SINR. Some companies believe that the scheme only has benefit if SINR is used, while other companies have concern that SINR is not feasible due to UE implementation dependency.

**Interference statistics** (stdev of interference): This scheme was evaluated by one company who observes even higher gain compared to statistical CQI/SINR. The main benefits and concerns are similar to statistical CQI/SINR. However, there is a significant additional concern related to the “explicit feedback” nature of the report which makes practical usability difficult considering varying UE receiver implementations. Based on company inputs, it seems unlikely that consensus on supporting this scheme is achievable in R17.

**CSI report based on worst IMR**: This scheme was evaluated by several companies and in most cases a gain can be observed. The main benefit of this scheme is that it is generally considered low complexity, although additional discussion would be needed for the definition of “worst-IMR” in case of sub-band CQI. A concern is that reporting of a “worst” CQI experienced in the recent past may not be representative of the worst CQI at a very low probability level.

**Worst-M CQI**: This scheme was evaluated by several companies and a gain is observed in most cases. The main benefit of this scheme is that it is low complexity, although additional discussion would be needed for the definition in case of multiple measurement resources in time domain. Similar to the previous scheme, a concern is that reporting of a “worst” CQI experienced in frequency domain may not be representative of the worst CQI at a very low probability level particularly when traffic is not periodic.

From the above, the schemes that have most support appear to be Statistical CSI/SINR (7 companies) and Worst-M CQI (8 companies). Between the two schemes, moderator suggestion is to take consideration of the complexity and time remaining in the work item. From this perspective, the worst-M CQI scheme appears preferable since a lot of potentially difficult discussions can be avoided (e.g. whether to use CQI or SINR, details of stdev estimation, quantization, etc.). The worst-M CQI scheme also appears to not present difficulty from perspective of testing. ~~By configuring frequent reporting of worst-M CQI in time domain, it may also be possible for a network implementation to infer CQI at very low probability and achieve the same objective as with reporting of standard deviation of CQI.~~

Although the definition of worst-M CQI is straightforward when considering a single measurement instance in time domain, the case of multiple measurement instances could be further investigated (e.g. whether to take average in time domain first, to take minimum in both frequency and time domains, etc.).

**FL proposal 8.1-1**: **Support new metric based on network configured channel and interference measurement interval, where new metric is a minimum CQI value at least in frequency domain (“worst-M CQI”).**

* **FFS: Definition with multiple channel and interference measurement instances within time interval**

For **increasing granularity of subband CQI**, this scheme could be utilized by the scheduler in the same way as worst-M CQI, or statistical CSI/SINR, by utilizing the reports to derive a low-probability CQI and achieve similar performance. However, several companies have concern that the overhead increase to achieve this would be prohibitive as reports need to be very frequent, and the increased payload by report would be 43% (for 3-bits D-CQI) or 87% (for 4-bits CQI) compared to legacy subband D-CQI. Another way that the scheme could provide benefit is by improving accuracy in case the scheduler selects subband based on the last reported CQI report, even though the results so far do not show consistent gains in URLLC scenarios at least with the CSI computation latency of R16.

Considering the concerns related to increased overhead, moderator suggestion is to agree that if new type of subband CQI with increased granularity is supported, the maximum number of bits per subband CQI value is 3.

**FL proposal 8.1-2: If increasing granularity of subband CQI is supported, the maximum number of bits per subband CQI is 3 bits.**

For **updating of CQI-only**, evaluation results with CSI processing time unchanged from R16 do not consistently show improvement from baseline with lower periodicity. One company observed improvement when reducing CSI processing latency to 0.5 ms. In view of these evaluation results, moderator suggestion is to only consider this scheme along with a reduction of CSI processing latency for the reports where only CQI is updated.

Some companies have concerns with deviating with the principle of transmitting self-contained CSI reports as it would introduce additional complexity to deal with missing CSI reports and error propagation. It was also pointed out that a type of CQI-only reporting very close to the proposed scheme could be achieved by configuration in R16. Considering these concerns, moderator suggestion is to agree that self-contained CSI reports would continue to be used if this scheme is supported.

**FL proposal 8.1-3**: **If reporting with CQI-only update is supported:**

* **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
	+ **Note: this does not preclude use of new report based on configured channel and interference measurement, if supported.**
* **Support shorter CSI computation time compared to R16.**

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

**Question 2-1**: Please provide feedback if you would like to either (a) make correction in this moderator summary (such as evaluation results or company position) or (b) add your company position relative to the schemes listed in the above.

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| Company | Yes/No | Comments |
| HW/HiSi |  | Given the diversified views from companies, we think it is difficult for the progress to have 3 separate proposals in Case 1 (one for each bullet from last meeting, i.e. statistic schemes, sub-band accuracy and for partial CQI update).Instead, we think progress could be better if we would have one common proposal that includes multiple schemes and we should make this decision early.Maybe this was not so clear from our paper, we are in general sceptical about the technical benefits of the schemes that were listed under the first bullet from last meeting’s agreement (i.e. the statiscal schemes) but we could accept one of them, if also other methods that in our view are more technical meaningful could be supported. Which of the candidate schemes under the first bullet to select, we don’t have a very strong view.  |
| Nokia |  | One comment on, **“Statistical CQI/SINR** (mean + stdev CQI/SINR): This scheme was evaluated by multiple companies and a significant gain is observed by most. The main benefit of this scheme is that it may provide the network with a good picture of the main characteristics of the CQI distribution (mean and standard deviation), from which the CQI at the tail of the distribution can be estimated. The main concern is the higher complexity (relative to other schemes) for the UE to obtain the quantities. “This is mainly capturing CQI distribution aspects only. But, knowing CQI distribution does not help compared to SINR distribution. It would be good to capture the difference of this two schemes. |
| Ericsson |  | Please update Ericsson view of the following:* 8.2.3 CSI based on worst IMR occasion (Case 1-5): Please add Ericsson to the list of companies that do not support this scheme;

Also, we disagree with moderator statement for “Worst-M CQI”: “By configuring frequent reporting of worst-M CQI in time domain, it may also be possible for a network implementation to infer CQI at very low probability and achieve the same objective as with reporting of standard deviation of CQI.” If frequent reporting, then existing CQI reporting (wideband, subband) can also provide probability information. The benefit of statistical CQI reporting is, the probabilisitic information can be provided to gNB without frequent reporting. Thus, it is incorrect to say that worst-M CQI can achieve the same objective as statistical CQI. |
| QC |  | A comment to simulation assumptions for “Statistical CQI/SINR” or “intf statstics”, is the interference assumed as a stationary random process? Theoretically, for those statistics report scheme to benefit gNB scheduduling, it requires a stationary prob model for CQI/SINR/intf, which does not hold in reality. To verify the gain showed in some companies simulation results, we need to know what is the stochasitic model is assumed for interference? Whether it is stationary and non-stationary. To FL: based on the above comment, please add QC to the the list of companies have concerns to Case 1-1 and Case 1-3.  |
| Moderator |  | @HW/HiSi: I can add “if supported …” for the first statistic scheme. However, for the detailed discussion within each scheme it will become difficult to manage to do all the work in same proposal.@Nokia: Added the following sentence to reflect the issue with CQI vs SINR: Another concern is the use of CQI versus SINR. Some companies believe that the scheme only has benefit if SINR is used, while other companies have concern that SINR is not feasible due to UE implementation dependency.@Ericsson: OK to add in list of non-supporting companies and to delete this statement on frequent reporting since this aspect was not discussed in the group. However, I still suspect that multiple “worst CQI” samples can be useful to estimate a low-percentile CQI (perhaps with less frequent reporting than with legacy CQI).@Qualcomm: Added Qualcomm to list of companies with concerns for 1-1 and 1-3. On your comment, my understanding is that the interference is not generated explicitly by stochastic model but is dependent on the traffic model assumed for the scenario. |

**Question 2-2**: Please indicate if FL proposal 8.1-1 is acceptable

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| Company | Yes/No | Comments |
| Sony | No | Information using worst M sub-band CQI can already be achieved with the existing sub-band CQI report. Unclear why we need to mechanisms to provide the same information.  |
| HW/HiSi | No | This proposal goes directly to support one scheme. At this stage, we think more discussion is needed and this proposal should be handled equivalently to the other proposals, i.e. start with “if supported,…”. Then, as indicated in our answer to Question 2-1, even if we are still sceptical about the technical benefits of the candidate schemes behind this proposal, for the matter of progress, we would like to work constructively on a compromise solution. We would think it could be great if we as a group could specify multiple schemes, e.g. partial CQI update and a statistical scheme. Which one to select from the statistic candidates, we don’t have a strong view. |
| Nokia | Yes | Wording could be improved, **“ minimum CQI value at least in frequency domain”** may be misunderstood by the companies. Other than that no big issue as this seems to be the most technically right decision that RAN1 can take on enhancing CSI feedback.  |
| Samsung | No | The gNB can obtain all information based on Rel-15 configurations. It is not even clear if the proposal can achieve even marginal overhead reduction for few 2-bit SB differential CQIs as it needs to indicate reported subbands. |
| Ericsson | No | Do not support Worst-M CQI.This method does not provide performance improvement for realistic sceanario where the interference is unpredictable in both time and frequency.  |
| Futurewei | No | Our performance evaluation results show that performance of Worst-M CQI is worse than both Case 1-3 (Interference statistics) and Case 1-1, with Case 1-3 having the best performance. Comparison of performance of different schemes should be the most important criteria to decide scheme(s) to be supported and that is why companies were encouraged to conduct performance evaluation of different schemes. Based on the performance comparison, we cannot support this proposal.  |
| QC | YES | FL proposal 8.1-1 is acceptable to us. We also support to extend worst-M scheme to scenario with multiple CMRs/IMRs configured in time domain. A minor editorial comment: “**new metric is a minimum CQI value**” means UE always report the worst CQI. However, our understand of Worst-M is that UE can be configured to report the worst M CQIs, not limiting to always report the worst (single) CQI.  |
| Moderator |  | @Nokia, QC: Thanks for support.@Sony, Samsung: I don’t think it can already be achieved with existing sub-band CQI report because the 2-bit D-CQI is not accurate when a subband CQI is much lower than wideband CQI. The same information would be provided with 3-bits or 4-bits subband CQI (which would increase overhead compared to R16).@HW/HiSi: I will change to “if supported” in the next update of proposals.@Ericsson: Performance improvement is shown even for AR/VR with latest results from Nokia that takes into account multiple IMRs (and also InterDigital results).@Futurewei: Performance is of course important, but not the only criterion. Specification and implementation complexity are important too.@Qualcomm: Thanks for support. My understanding so far was that this would be a single value but whether to report also e.g. second worse could be next level of discussion. |
| ZTE | No | The worst-M CQI focusing only on frequency domain cannot resolve the CSI uncertainty in the time domain due to the interference fluctuation. We propose to extend this method to both frequency domain and time domain with the following update. This can further reduce the report overhead and avoid the frequent CSI report.**FL proposal 8.1-1**: **Support new metric based on network configured channel and interference measurement interval, where new metric is a minimum CQI value at least in frequency domain and time domain (“worst-M CQI”).*** **FFS: Definition with multiple channel and interference measurement instances within time interval**
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| LG | Yes | We support the proposal. Among candidates of Case 1, we think worst-M CQI is most feasible options to support. We share Nokia and Qualcomm’s view on “**minimum CQI value**”. It would be good to fix.  |
| Quectel | Yes/ Neutral | The worst-M CQI scheme is acceptable for us as some performance gain can be observed based on simulation results from a number of companies. We are open to extend this method to time domain. |
| Intel | No | As commented online, we struggle to see why this scheme is suggested for further focus while statistical CSI has similar support, and similar level of evaluation.To move forward, suggest to either put Case 1-1 and 1-6 for further down-selection, or to make configurable between these two cases. |
| HW/HiSiUpdate 1 | No | Moderator: Thank you, for being open to add “if supported,…” to this proposalI am a bit surprised about companies’ answers in case 1 (to all three proposals). It seems many intent directly to decide now whether to support a scheme or not. But in my understanding that is not the goal of the proposals: they all start with “if supported…” and then only intend to narrow down the options for each scheme.As we said during previous comments and during on-line, we are open to specify a multiple schemes under case 1. From the technical side we are skeptical to the schemes covered included under this bullet.It has been stated by proponents that these schemes have shown gains but most simulations have not considered that all the calculations also can be done at the gNB. Thus, the comparison is not done versus a fair baseline. And also, some of the simulation that are presented do not show gains. |
| Nokia 2 |  | Few comments, We agree with the comments from FL towards Sony, SS, E///. @ZTE >> We tend to agree that capturing both f and T domain interference is important, as you suggested. We could clarify that as below as a compromise solution. @Intel >> we were supportive of Case 1-1, but the specification work may be bit high with the time we have in WI. @HW >> to progress, we have to decide one scheme for case 1. If you have any compromised suggestion in the lines that showed in performance gains, please feel free to bring it up. We would be ok to discuss as long as it makes sense. **FL proposal 8.1-1**: **Support new metric based on network configured channel and interference measurement interval, where new metric is a minimum CQI value at least in frequency domain (worse-M sub-bands) and time-domain (e.g. worse IMR instance).*** **FFS: Definition with multiple channel and interference measurement instances within time interval**
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| Moderator |  | @Intel: The suggestion is based on the expected amount of specification impact, and we also note that there is no consensus among Case 1-1 proponents on whether the scheme is based on CQI or SINR which adds another difficulty. Regarding Case 1-5, we think the same objective can be reached with Case 1-6 when time domain is considered. Hope it is ok with you if we continue in this direction.@Nokia2: Thanks for suggestion, this looks reasonable. |

**Question 2-3**: Please indicate if FL proposal 8.1-2 is acceptable

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| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | We think both a 3-bits differential CQI or full 4-bit for CQI should be included, this gives more flexibility. Which one to use could be configured by the network. It is straight forward and does not require a large specification effort.We disagree with that the overhead always is larger for the 4-bit absolute CQI. It depends on how many sub-bands are configured. For three sub-bands, for example, 3 extra bits are needed for the sub-band report, but then the 4-bit wideband CQI does not need to be reported. In that case the 4-bit sub-band CQI would have 1 bit less overhead. In general, the overhead difference between these two schemes is not significant, and if a certain use case would rather need low UL overhead than reporting accuracy, then the gNB always has the possibility to stick to the legacy report with 2 bits.Additionally, it is our view that an improved reporting accuracy also requires improved accuracy of the measurements. The measurement accuracy of the CQI can be improved with scheme 1-11 (if a faster CQI calculation time is supported). In our view 1-8 and 1-11 with faster CQI processing time should be supported together. |
| Nokia | No | This was discussed a lot in the past and never adopted due to the significant overhead. We do not think that this is practically useful. Frequent reporting has to configure to know interference variation, and a very large overhead is not helping. From our view, this enhancement is more for eMBB than URLLC.  |
| Samsung | Yes/Neutral | It can be acceptable because it is trivial to support, up to the gNB to configure the number of bits, and we observe some small gains at the 5% geometry CDF. |
| Ericsson | No | Do not support increasing granularity of subband CQI (Case 1-8).With 3-bit granularity, this method still increases CSI overhead significantly (>=39% for 100 PRB BWP [3]). On the other hand, performance benefit from this method does not justify the overhead. It improves performance only when interference is predictable w.r.t time but not frequency. There is little performance gain when interference is un-predictable w.r.t both time and frequency, which is typical in real life operation. |
| Futurewei | Neutral | We are open to discuss if both 3-bit and 4-bit subband CQI can be considered and whether 3-bit or 4-bit is used can be configured by gNB. |
| Moderator |  | @Sony, Samsung: Thanks for support.@HW/HiSi: There may be some cases where 4 bits has less overhead than 3 bits but for the majority of scenarios 4 bits seems worse.@Nokia, Ericsson: this proposal is not to agree on supporting it, but rather to agree that we would not go over 3 bits. (There is the phrase “if supported”). It means the same as “do not further consider 4-bits subband CQI”. With this formulation would it be acceptable to you? |
| ZTE | Neutral | It can improve the CSI report accuracy for sub-band in theory at the cost of the report overhead. We are open to discuss this method. |
| OPPO | Neutral | We are open to discuss further.  |
| LG | Neutral | We are fine to have upper bound at least for evaluation and liming its drawback for discussion perpose. We are open to discuss further on this issue.  |
| Quectel  | Neutral | We are open to study this method. More accurate CSI could be derived by gNB at the expense of increased overhead. gNB can decide whether a more accurate CSI or a lower overhead is more desired. |
| Intel | Neutral | The enhancement on its own does not provide gains based on our studies. Suggest to handle together with other Case 1 schemes, which benefit from the improved granularity. |
| HW/HiSiUpdate 1 | No | We agree with Intel that 1-8 should be combined with other schemes. 1-8 improves the reporting and 1-11 improces the CQI measurement. They could be combined, espeically because 1-8 is very simple from the spec impact.**From Moderator: @HW/HiSi:** There may be some cases where 4 bits has less overhead than 3 bits but for the majority of scenarios 4 bits seems worse.*Answer: We think in general the question about 3-bit differential CQI or 4-bit full CQI is not so much about overhead. With my previous comment I wanted to point out that they can be somewhat comparable in terms of overhead. And if the overhead would be the main motivation for a specific use-case, then the gNB can configure the 2-bit legacy CQI. We think the 4 bits CQI give more flexibility and supporting both is also fine since the spec impact is low. It could be made up to gNB configuration.*Previous comment for completeness:We think both a 3-bits differential CQI or full 4-bit for CQI should be included, this gives more flexibility. Which one to use could be configured by the network. It is straight forward and does not require a large specification effort.We disagree with that the overhead always is larger for the 4-bit absolute CQI. It depends on how many sub-bands are configured. For three sub-bands, for example, 3 extra bits are needed for the sub-band report, but then the 4-bit wideband CQI does not need to be reported. In that case the 4-bit sub-band CQI would have 1 bit less overhead. In general, the overhead difference between these two schemes is not significant, and if a certain use case would rather need low UL overhead than reporting accuracy, then the gNB always has the possibility to stick to the legacy report with 2 bits.Additionally, it is our view that an improved reporting accuracy also requires improved accuracy of the measurements. The measurement accuracy of the CQI can be improved with scheme 1-11 (if a faster CQI calculation time is supported). In our view 1-8 and 1-11 with faster CQI processing time should be supported together. |
| Nokia 2 |  | @moderator >> We do have concerns on SB reporting and declaring that as URLLC solution. As long as companies are sensible to doing something important like 8.1.-1, we may not object to this mentioning of ‘if supported’.  |
| Moderator |  | @HW/HiSi Update 1: Thanks for further comment. However, I disagree with this statement: *We think in general the question about 3-bit differential CQI or 4-bit full CQI is not so much about overhead*. The concerns about 1-8 are -only- about overhead. If 4-bits CQI has more overhead than 3-bits D-CQI in almost all scenarios then it is clearly worse from that perspective. |

**Question 2-4**: Please indicate if FL proposal 8.1-3 is acceptable

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| Company | Yes/No | Comments |
| Sony | No | No point leaving this still open given that it did not have overwhelming support. |
| HW/HiSi | [Mostly Yes] | We are supportive in principle to this scheme but would like to keep some detail for FFS for now. We are fine with the sub-bullet to support a shorter CSI computation time. This is the most important part of this scheme and it would ne good to decide it now.For the self-contained reports, we would like to keep it FFS at this stage. According to our understanding, also in Rel-16 CQI can for example be reported without PMI. There is configuration where only CRI/RI/CQI is reported. Also, maybe other methods like a pre-configured rank and an assumption on the precoding matrix could be used.  |
| Nokia | No | We showed the performance loss with this approach and do not think solving the concerns on accurate MCS selection even with faster feedback |
| Samsung | Neutral/No | Overhead benefits are not applicable because “CQI-only” can be achieved based on Rel-15 configurations (e.g. with rank restriction for a given configuration).Timeline reduction may exist for the “best-case” wideband CQI reporting but it will be marginal (e.g. 1 symbol at 15 kHz SCS) and there will be some spec/UE impact associated with its support.  |
| Ericsson | No | Do not support reporting CQI-only update (Case 1-11).As discussed in our contribution [3], this method has numerous issues such as violating the self-contained principle in NR CSI design. Regarding “shorter CSI computation time”: this is only applicable for the instances where CQI-only is updated, and it is not applicable in the instances when RI/PMI are reported. |
| Futurewei | Neutral | We are open to have further discussion on this and potential combination of Case 1-11 with other Case 1 scheme(s). |
| QC | No | We need to be careful about the CSI process time reduction. On paper, yes, it seems UE processing time can be reduced with CQI report only. However, timeline reduction heavily depends on UE modem implementation details. We don’t think we can commit to “**Support shorter CSI computation time compared to R16**” at this stage. We can accept changing it to “**FFS: whether it is feasible to** **Support shorter CSI computation time compared to R16**” |
| Moderator |  | @HW/HiSi: It seems that the non-self-contained reports would be a big problem for other companies. This is why I suggest to remove it.@Ericsson: Not sure I understand your comment, because the proposal removes the violation of self-contained principle by stating everything would be reported in same instance as usual (thus no overhead reduction, only shorter computation time). Do you still think there is a problem with this aspect (or perhaps the formulation is not clear)? Also, similar to previous proposal there is “if supported” so this is not to agree on supporting the scheme.@Qualcomm: If we keep reports self-contained and do not reduce the CSI computation time then in my understanding there is no justification for this scheme. How about “Support shorter CSI computation time compared to R16 **(FFS: how much reduction is possible)**”? |
| ZTE | No | For this method, we should discuss whether and how many symbols the CSI processing time can be reduced first since the performance gain highly depends on the reduced CQI processing time. However, we have the concern on the performance because the current processing time is quite short.  |
| OPPO | Yes | One of key motivations to have the CSI enhancement for URLLC is to pursue the fast AP CSI feedback to match low latency of URLLC traffic, so that the AP CSI information can be available when the CSI information is needed for scheduling.  |
| LG | Yes | We supports the proposal. For self-contained CQI, our understanding is that UE updates CQI only but transmit all CQI/RI/PMI as like Rel-16. Though we are fine with this approach, we are also open to discuss further how to trigger and contruct CQI reporting for this scheme.  |
| Quectel | No | We need to firstly have a common understanding on whether CSI processing time can be reduced and to what extent the processing time can be reduced.  |
| Intel | No | Removing the OH saving feature and relying only on potentially faster CSI computation time makes this feature almost useless. It was shown by companies in previous meetings, that the faster CSI does not solve the URLLC-specific interference burstiness issue. |
| HW/HiSi | Yes | Moderator @HW/HiSi: It seems that the non-self-contained reports would be a big problem for other companies. This is why I suggest to remove it.Answer: We still think it is not a problem, but if really needed, we are fine to accept it.In our view case 1-11 is a scheme that really provides an enhancement. Here, it will be possible to enhance the CSI processing time. This will be an obvious enhancement of Rel-16 as opposed to the schemes under poropsal 8.1-1, which also can be achieved by gNB implementation.Based on the comments from opponents. It seems many are not so negative as such but are concerned what processing time reduction can be reached, would it help if we include this in the proposal?**Potential proposal**: **If reporting with CQI-only update is supported:*** **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
	+ **Note: this does not preclude use of new report based on configured channel and interference measurement, if supported.**
* **Support shorter CSI computation time compared to R16.**
	+ **Processing delay from sub-band CQI is reduced to numbers corresponding to the fast CSI delay in Rel-16**

Below some comments to companies who have a negative view about these schemes, hope I can convince some of you ☺**@Nokia:** The performance that is shown in your simulations is for partial CQI without fast processing. This proposal here is coupled to a reduced CQI processing time. Therefore, the simulation results cannot be considered directly. In your simulations, you have a high reporting frequency, but the time gap between measurements and reports is according to the legacy CSI delay. I think with reduced latency you could see an improvement. Additionally, for all enhancements, we can find cases where there is no gain. One single simulation scenario should not be taken to preclude a scheme.**@Samsung**: The time-reduction for the fast wide-band CQI is not the main target. What we have noticed is that the legacy sub-band CQI delay is very large in Rel-16. For many URLLC use cases, we think that sub-band CQI should be employed. And these delays could be reduced significantly with partial CQI update. We think that delays similar to the fast CSI delay processing in rel-16 are achievable. Then also the “normal” wideband CQI delay can be reduced. **@Ericsson:** For the self-contained principle. We don’t see the need, but we are ok to accept that. For your second comment, we think there are many use cases where PMI/RI do not need to be updated. And the gNB would have full control about it. Also, the rank could be pre-configured and the PMI could be obtained from SRS. One question, one the PMI not being updated, isn’t that more of an issue for case 1-1?**@QC:** From your answer I have the impression that you are not so negative about the scheme, but want to be sure that it is feasible to reduce the CQI processing time. I think that is a fair concern, and the proposal at the moment is saying “if supported”. Thus, there is still the possibility for you to do further checking. In general, Oppo mentioned in their paper that the complexity can go down from O(196) to O(1), which gives a good indication for that a reduced processing time is feasible. **@ZTE:** The proponents have a clear picture about how much to reduce the processing time (e.g. comparable with N1 or in the range of the fast CSI delay from Rel-16). This is a concrete design target, so the discussion could become very constructive and focused. You mentioned that the current processing time is short, this is only the case for the fast CSI which has too many restrictions (e.g. only wideband, no data included). The current CSI processing time is too long (especially for sub-band CQI but also for the “normal” wideband CQI). If we want to reduce those values eventually, we will have to discuss it some time. So why not now when the have the agenda item that would allow this?**@Quectel:** Same answer as to ZTE. The proponents target for a processing time reduction to cut the normal wideband-CQI and the sub-band CQI to similar delays as for the fast CSI delay in Rel-16. Also the proposal says: “if supported…” and is tied to processing reduction. Would you be fine with agreeing to the proposal, is a goal for the processing reduction in set**@Intel:** Would you be fine if the overhead saving feature is re-added? To your performance comment, we disagree. In our simulations presented last meeting we evaluated the impact of when the channel measurement is per4formed closer to the scheduling, which is a generally applicable scenario. Both for URLLC and other conditions. For this meeting, added new simulations, that evaluate the URLLC performance in the presence of eMBB+URLLC UEs in the factory environment.  |
| Nokia 2 |  | **@HW:** Your reply was “The performance that is shown in your simulations is for partial CQI without fast processing. This proposal here is coupled to a reduced CQI processing time. Therefore, the simulation results cannot be considered directly. In your simulations, you have a high reporting frequency, but the time gap between measurements and reports is according to the legacy CSI delay. I think with reduced latency you could see an improvement. Additionally, for all enhancements, we can find cases where there is no gain. One single simulation scenario should not be taken to preclude a scheme.”The above is not correct. It is not clear how can you say that the results are not coupled with a reduced CQI processing timeline when we even simulate sub-band CSI (CQI) with faster reporting than what is feasible now. We use the latest measurements, and the gap between measurement and reporting is lower when the reporting periodicity is faster. There is a loss even with a higher overhead of reporting in partial CQI. It is not hard to understand the fundamental issue of this scheme. The results from multiple companies show that the incorrect CSI (even with faster reporting) does not help gNB in interference with varying channel environment.  |
| Moderator |  | @HW/HiSi: Thanks for suggestion on clarifying the processing time reduction that would be targeted. |

## E-mail discussion (2nd round) for Topic #2

In view of the comments, the proposals are updated as follows.

To facilitate progress, moderator proposes 8.2-0 to agree on at least eliminating two of the four candidate schemes within “network configured channel interference measurement interval”. Scheme “interference standard deviation” is eliminated in view of the large number of companies that have concern (see section 8.2.2 for details). Scheme “CSI based on worst IMR occasion” is eliminated because the same objective can be reached if time-domain is considered within “worst-M CQI”.

**FL proposal 8.2-0**: **For the new metric based on network configured channel and interference measurement interval (if supported), do not consider further the following schemes:**

* **Interference standard deviation**
* **CSI based on worst IMR occasion**
	+ **Note: this does not preclude minimum CQI value in frequency and time domain**

Other proposals are modified as follows:

**FL proposal 8.2-1**: **If supported,** **~~Support~~ the new metric based on network configured channel and interference measurement interval~~, where new metric~~ is a minimum CQI value at least in frequency domain and time domain (“worst-M CQI”).**

* **FFS: Definition with multiple channel and interference measurement instances within time interval**

**FL proposal 8.2-2**: **~~If~~ For increasing granularity of subband CQI, ~~is supported, the maximum number of bits per subband CQI is 3 bits~~ do not further consider 4-bits subband CQI.**

**FL proposal 8.2-3**: **If reporting with CQI-only update is supported:**

* **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
	+ **Note: this does not preclude use of new report based on configured channel and interference measurement, if supported.**
* **Support shorter CSI computation time compared to R16.**
	+ **Target “CSI computation delay requirement 1” for subband report in which only CQI is updated.**

**Question 2-5**: Please indicate if FL proposal 8.2-0 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | As we commented previously, we have conducted performance evaluations for Case 1-1 (Statistical CSI/SINR), Case 1-3 (interference statistics), Case 1-5 (CSI based on worst IMR occasion), and Case 1-6 (Worst-M CQI), and our performance evaluation results show that performance of Case 1-3 is the best among the four schemes, with significant performance gain (up to 29%) over the other schemes. We also compared the performance of Case 1-3 to gNB-implementation-based scheme, and our results show a performance gain of 76% over the gNB-implementation-based scheme. The reporting overhead of Case 1-3 is low since its reporting period can be much longer than the CQI reporting period (e.g., 20 times of the CQI reporting period). Case 1-3 does not requires the UE to report “explicit” or “absolute” interference level that it measures. What the UE reports is the variance/standard deviation of its measured interference, which needs to be measured anyway by the UE based on its assigned CSI-IM or NZP CSI-RS. We have strong concern on how the proposals were formulated where scheme with the best performance and with significant performance gain over other schemes is proposed to be eliminated, while scheme with no performance gain or even performance loss is proposed to be kept. In our opinion, as a first step, the group should be looking at performance comparison of different schemes, and comparison of performance of different schemes should be the most important criteria to decide scheme(s) to be supported. That is also why companies were encouraged to conduct performance evaluation of different schemes.  |
| Samsung | Yes | No point relying on temporary interference statistics or assuming that the interference follows any particular distribution and is not random. |
| vivo | Yes |  |
| QC | Yes |  |
| DOCOMO | Yes | Share similar view as Samsung. Besides, we think we should not rely on only performance but also other perspectives like spec impact for down-selection (considering the limited time).  |
| Intel | Yes | Agree with the smaller progress by eliminating the above schemes. We can further discuss this week common design aspects between the two other survived schemes. |
| ZTE |  | We can accept this proposal only if the proposal 8.2-1 is agreed. |
| Nokia |  | Same comment as ZTE. We could have this case 1 in a single proposal.  |
| HW/HiSi | No | 8.2-0 and 8.2-1 should be discussed together.Proposals 8.2.0 and 8.2-1 seem to overlap. * In proposal 8.2.0, the worst IMR occasion is precluded, whereas in 8.2-1 the time-interval is still open for discussion. Cold the difference be clarified?
* The technical pros/cons for statistical CSI/SINR and interference standard deviation are similar and the same goes for worst M\_CQI and worst IMR occasion. We don’t see how on a technical basis statistical CSI would be preferred compared to standard deviation of interference or why worst M-CQI would be preferred over worst IMR occasion.

We think one way to progress would be on a high level to make an agreement for package consisting of non-mutual exclusive schemes that can be applied for different use cases.**FL proposal 8.2-0**: For CSI enhancements in rel-17, * Faster CSI processing time based on CQI update only is supported
* A new metric for a statistical scheme, based on network configured channel and interference measurement interval, e.g.
	+ is a minimum CQI value at least in frequency domain and time domain (“worst-M CQI”).

Interference standard deviation or statistical CSI/SINR |
| Sony | Yes | What happen to mean/standard deviation for CQI/SINR? |
| OPPO | Yes |  |
| Ericsson | Yes |  |
| Moderator |  | @Futurewei: The concerns about using interference as a metric still stand even if it is standard deviation. Please realize that your proposal has the least support and the highest number of companies with concerns. Blocking progress in this situation is not constructive.@HW/HiSi: Thank you for suggestion. For the next round I am proposing a package of schemes.@Samsung, Vivo, Qualcomm, DOCOMO, Intel, Sony, Oppo, Ericsson: Thanks for support. |

**Question 2-6**: Please indicate if FL proposal 8.2-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | As we commented on FL proposal 8.2-0, our performance evaluation results show that performance of worst-M CQI is much worse than interference statistic. Based on the performance comparison, we cannot support this proposal. |
| Samsung | No | To repeat a same comment, the gNB can already obtain that information. There may be a somewhat smaller quantization loss for the differential values but, from our evaluations for a larger number of bits to represent those values, any gain is marginal. Even if such gain were to be obtained, it could by using 3 bits instead of 2 bits which is a much simpler approach without any material difference in CQI reporting overhead.  |
| vivo | No | Even worst-M CQI covers both the frequency domain and time domain, the worst-M CQI still cannot resolve the channel and interference variation in time domain, since only partial information is reported.On the other hand, compared to the full subband CQI reporting with the same reporting interval, the worst-M CQI reporting provides no additional information thus no performance gain can be achieved compared to that, while the complexity to derive the full subband CQI and worst-M CQI remain the same.  |
| QC | Yes |  |
| DOCOMO | Yes |  |
| Intel |  | To cover additional functionality supported by us and other companies, suggest modicaiton:**FL proposal 8.2-1**: **If supported,** **~~Support~~ the new metric based on network configured channel and interference measurement interval~~, where new metric~~ is a ~~minimum~~ CQI value corresponding to a specified filtering of the measurements at least in frequency domain and time domain ~~(“worst-M CQI”)~~.*** **FFS: filtering function (e.g. minimum, mean, std dev, maximum etc)**
* **FFS: Definition with multiple channel and interference measurement instances within time interval**
 |
| ZTE | Yes | We are fine with this proposal. Since it is extended to the time domain and frequency domain, we think it is better to remove the worst M CQI from the main bullet to avoid misunderstanding (worst-M CQI means the CQI for the worst M subband). Also, we are fine with Intel’s updates. |
| Nokia | Yes | Not ok with Intel’s suggestion as RAN1 specs (e.g. CQI reporting) do not define filetring as such. It would be bit further complicating the discussion.  |
| HW/HiSi | No | As ZTE also pointed out, 8.2.0 and 8.2.1 should be discussed together.Proposals 8.2.0 and 8.2-1 seem to overlap. * In proposal 8.2.0, the worst IMR occasion is precluded, whereas in 8.2-1 the time-interval is still open for discussion. Cold the difference be clarified?

The technical pros/cons for statistical CSI/SINR and interference standard deviation are similar and the same goes for worst M\_CQI and worst IMR occasion. We don’t see how on a technical basis statistical CSI would be preferred compared to standard deviation of interference or why worst M-CQI would be preferred over worst IMR occasion. |
| Sony | No | Worst M-CQI can be achieved using a higher granularity sub-band CQI report, which has more information. |
| OPPO | No | worst-M CQI handles only frequency domain channel information by its definition. What is the worst-M CQI with time-domain handling? |
| Ericsson | No | “Worst-M CQI” simply does not provide adequate statistical information to assist with gNB scheduler. The scheduler still needs to estimate and add backoff in MCS selection in order to achieve the high reliability requirement like BLER=1e-5. We fail to see the benefit compared to how existing link adaptation is done. |
| Moderator |  | @Samsung: There is a big difference in reporting overhead between this proposal and 3-bit D-CQI. In this proposal, the payload may be as low as 4 bits W-CQI + 4 bits min-CQI + (possibly subband indication if needed).@vivo, Sony: yes it can be achieved (if e.g. 3-bits D-CQI is supported) but with much higher overhead. If the network does not want this extra overhead compared to R16 and only need the min value, this scheme is useful.@HW/HiSi: See next round where proposals are combined. Here the proposal is to focus on “minimum” CQI in time and frequency, combining the benefits of “worst-M CQI” and “CSI based on worst IMR occasion”. Standard deviation schemes are down-selected in this proposal. @Oppo: The proposal is to take a minimum in time and frequency@Ericsson: Possibly, the uncertainty on the required backoff is reduced. Gains were observed in evaluations.@Qualcomm, DOCOMO, ZTE, Nokia: Thanks for support. |

**Question 2-7**: Please indicate if FL proposal 8.2-2 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | As we commented previously, we are open to discuss if both 3-bit and 4-bit subband CQI can be considered and whether 3-bit or 4-bit is used can be configured by gNB.  |
| Samsung | Yes | Just for the sake of progress although the benefit is unclear (4 bits is removed while 3 bits remains for further consideration). |
| Vivo | Maybe Yes | We are not sure whether we need to do this for Case 1-8 right now. In fact, we think the most important thing is to decide to support increasing granularity of subband CQI and how many bits will be used. |
| QC | Yes |  |
| DOCOMO | Yes |  |
| Intel | Yes | Agree to focus on 2 bit vs 3 bit only |
| ZTE | Yes | We are fine with this proposal. |
| Nokia | Partly | Suggest to have a single proposal as companies can to come to a compromised direction for further discussion.  |
| HW/HiSi | No | Agree with Nokia to have a single proposal for case 1 so that comoanies can come to compromise solution.We think the standard effort for 4-bit CQI is smaller than for 3 bit. Since no new table needs to be defined.Also, 4-bit CQI would allow more flexibility, since it does not require to calculate the wideband CQI as reference.The overhead between 3 bit and 4 bits is comparable.We don’t see a reason why 3-bit sub-band should be generally preferred over 4-bits.This method makes mostly sense if it would be combined with a more accurate CQI measurement, it should be bundled with partial CQI update. |
| Sony | Yes | This is probably the easiest to specify. |
| OPPO | Yes | We are ok if this proposal (if agreed) could help further progress.  |
| Ericsson | Neutral | The proposal should not be understood as “support increasing granularity of subband CQI”. The original version of FL proposal 8.2-2 is preferred. That is, “If supported, max is 3 bits”  |
| Moderator |  | @Futurewei: If you are “open” to both possibilities, then you should be fine with this proposal.@Nokia, HW/HiSi: ok to have single proposal (see next round) @HW/HiSi: As previously discussed, overhead with 4 bits is higher in vast majority of cases. Regarding bundling with partial CQI update, I believe other companies think this scheme is useful independently of it so maybe better to keep separate for now.@Samsung, Qualcomm, DOCOMO, Intel, ZTE, Sony, OPPO, Ericsson: Thanks for support (or neutral). |

**Question 2-8**: Please indicate if FL proposal 8.2-3 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | Neutral | We are open to have further discussion on this and potential combination of Case 1-11 with other Case 1 scheme(s). |
| Samsung | No | If there is any further consideration for that proposal, the second sub-bullet (including its sub-bullet) should be removed. We do not agree to support shorter CSI computation time (it is the tightest UE processing requirement). We also question the need for the first sub-bullet as its functionality can be provided in R16 by gNB configuration of CSI reports (configure one CSI report with “cqi, ri, cri” and rank restriction). |
| QC | No | Similar view as Samsung, the second bullet on shortening UE processing time should be removed. As we commented before, CSI processing time heavily dpends on UE implementation. The paper design here may not able to translate to processing time reduction, as some companies wished. How can some companies know that all UE vendors could reduce CSI processing time to CSI computation delay requirement 1 (which is the tightest equirements) by applying this scheme to subband report?* **~~Support shorter CSI computation time compared to R16.~~**
	+ **~~Target “CSI computation delay requirement 1” for subband report in which only CQI is updated.~~**

We also question the whether there is performance gain with the scheme. Comparing to a full report with same feedback periodicity, we don’t believe the scheme can provide any gain, which is just physically/mathmetically impossible.  |
| DOCOMO | Neutral | We are open to have further discussion on this. |
| Intel |  | We are wondering if this proposal is reverting the following agreement: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

In our understanding, in current form there is no new CSI reporting quantity/type being defined – only a restriction to update CQI only – which means we precluded already enhanced CSI computation time for this. |
| ZTE |  | We can accept this proposal if this is the majority view. |
| Nokia | Partly  | As a solution, we do not support this yet. But, to make progress we can include this with other proposals in one compromised proposal.  |
| HW/HiSi | Yes | Agree with Nokia. We should find a compromise solution. |
| Sony | No | This solution hinges on its ability to process CQI faster which is unproven and subject to UE implementation. It doesn’t really give better performance. |
| OPPO | Yes | In our understanding, “CQI-only update” intends to have a new reporting type/content (although still reusing the existing CSI reporting quantity as proposed) that targets to allow shorter processing time. This is consistent to the 2nd bullet of the Intel-referred RAN1 agreement.  |
| Ericsson | No | The benefits of the scheme are pretty much all lost. First bullet means there is no reduction in reporting overhead. Second bullet would have been useful, but it seems that several UE vendors reject the possibility of CSI computatino time reduction.Additionally, existing CSI configurations can achieve the same as Case 1-11. Thus, we see no reason to explore Case 1-11 further. |
| Moderator |  | @Samsung, Qualcomm: OK to have this as FFS@ZTE, Nokia, DOCOMO, Futurewei: Thanks for being open to compromise.@Intel: I am not sure if this is common understanding.@Sony: HW/HiSi has observed gains with reducing CSI computation time.@Ericsson: Maybe some reduction could be explored, as FFS. |

## E-mail discussion (3rd round) for Topic #2 and Topic #3

For this round of comments, a single proposal inclusive of a set of non-mutually exclusive schemes is presented.

Moderator understands that most companies have concerns on at least one of the schemes of the list. However, at this time the proposal below seems the best that is possible to achieve consensus if all companies are open to compromise. Please be constructive and understand that other companies would be making compromise too!

**FL proposal 8.3-1**:

**Support at least one of the following for CSI enhancements for IIoT/URLLC:**

**~~If supported, the~~**

* **A new metric based on network configured channel and interference measurement interval:**
	+ **minimum CQI value at least in frequency domain and time domain ~~(“worst-M CQI”)~~.**
	+ **FFS: Definition with multiple channel and interference measurement instances within time interval**
* **~~For~~ 3-bits differential subband CQI (for increasing granularity of subband CQI) ~~do not further consider 4-bits subband CQI~~.**
* **~~If~~ Reporting with CQI-only update ~~is supported~~:**
	+ **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
		- **Note: this does not preclude use of minimum CQI value ~~new report based on configured channel and interference measurement, if supported~~.**
	+ **FFS: Support shorter CSI computation time compared to R16.**
		- **FFS: how much reduction of CSI computation time is possible**
		- **~~Target “CSI computation delay requirement 1” for subband report in which only CQI is updated.~~**
* **~~If supported, for the~~ Reporting of delta-~~CQI/~~MCS:**
	+ **Report consists of delta-MCS for a TB received with MCS index IMCS:**
		- **delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
		- **FFS: How UE determines BLER target (e.g. explicitly indicated by network or linked to a CQI table)**
	+ **FFS: Number of bits for delta-MCS report**
	+ **FFS: whether delta-MCS is reported (Option 1) jointly with HARQ-ACK codebook or (Option 2) separately from HARQ-ACK codebook.**

**Question 2-9**: Please indicate if FL proposal 8.3-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| vivo | Yes in general | We are generally fine with the proposal.We have a comment on the the first bullet. We think more clarifications on how to report the minimum CQI value at least in frequency domain and time domain are needed. For example, whether and how to indicate the frequency info and/or time info for the minimum CQI value? If only one single minimum CQI value is reported, this frequency/time information may not be necessary. But it still can be useful for gNB to identify the worst CQI in frequency and time domain. If multiple minimum CQI values are reported, it is necessary to report the corresponding subband and/or time instance. Given these open issues on the minimum CQI value report, we suggest to add a FFS on whether/how to indicate the frequency info and/or time info for the minimum CQI value. |
| Sony | Yes |  |
| LG | Yes | We are supportive to this proposal for the sake of progresses. Regarding joint reporting between delta-MCS with HARQ-ACK codebook, it should be considered whether this is in our scope and side effect on other AI. Now we are assuming to support one or multiple CSI report schemes. If multiple CSI report scheme are supported, then we think it is necessary to discuss whether to unify them if possible and how to merge/prioritize them if they are overlapped.  |
| HW/HiSi | No | We think that more refinement of the individual schemes is needed before committing to the support of at least one. In general we could be fine with a compromise later on but more technical discussion is required firstly, especially because some of the proposals seem to bring the discussion back to an earlier stage.For the minimum CQI We have the same question as vivo. Also, we think this could be calculated directly at the gNB based on Rel-16 reporting. For the sub-band CQI Could it please be clarified why 3 bit D-CQI is proposed instead of 4 bit CQI? Is it really just the overhead argument? If only one of the two enhancements shall be taken, we think it should be 4 bit absolute CQI, because:* We think it goes better together with the minimum CQI value from the first bullet (worst CQI). In that case the worst CQI could be reported as a 4-bit sub-band CQI.
* The overhead of 3-bit differential or 4-bit absolute sub-band CQI is comparable. There are cases where the 4-bit has less overhead (because wideband CQI does not need to be reported) and there are cases (maybe some more) where the 3-bit D-CQI has less overhead. However, overhead is not the motivation to enhance the sub-band accuracy. If overhead would be the main concern then the gNB could directly use the legacy 2-bit sub-band CQI. The main motivation is the reporting accuracy, and the 4-bit sub-band CQI has no quantization loss as opposed to the 3-bit CQI.
* The standard is effort is less, since the 4-bits CQI table can be re-used
* The UE is not required to calculated the wide-band CQI

As a compromise we are fine to support that the gNB can configure, 2-bit differential report, 3-bit differential report or 4-bit report. In this way, the gNB could control the overhead, and select which one is better in a certain scenario.***Suggested Proposal: For enhanced sub-band CQI reporting, down-select between the following two options:**** ***Option 1: RRC configuration of enhanced sub-band reporting, gNB can configure 3 bits differential subband CQI or 4 bits sub-band CQI (for increasing the granularity of the sub-band CQI***
* ***Option 2: 4 bits sub-band CQI (for increasing the granularity of the sub-band CQI)***

For the partial CQI updateWe think that the newly introduced FFS from the bullet to support shorter CSI computation time should be removed again. Otherwise, it would throw us back in the discussion some steps. There seems to be consensus already that a reduced CQI computation time is the key benefit of this scheme. We assume that the FL’s motivation for setting FFS before the computation time reduction is based on the comments from QC and SS, that they are not sure if the processing time can be reduced. We think this might depend on the conditions that are applied for the fast partial CQI (e.g. number of configured CSI resources) and could be discussed further. The second FFS in the subbullet could be more specified for better progress. We think that the problem with the legacy CSI computation time is mainly the long duration for delay requirement 2. Therefore, we could focus on a reduction compared to that. Based on the above discussion, we think the proposal could be updated as follows: * **~~FFS:~~ Support shorter CSI computation time compared to R16.**
	+ **FFS: how much reduction of CSI computation time is possible compared to delay requirement 2 and under which conditions.**

For the delta-MCS reportWe still have a concern on the sub-bullet below and prefer to have it FFS:* + **FFS: delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**

The reason is that we firstly need to discuss/agree if the UE can use any target BLER and should apply the same target BLER as what has been used for the scheduled TB. If the group can agree on this, we are fine to accept the above bullet as a compromise, i.e. the delta-MCS would be based on IMCS.. However, if there could be a mismatch between used target BLER for MCS calculation and for the scheduled TB, the above bullet should be discussed further.For the FFS bullet below, could it please be explained what “linked to CQI table” means, since the scheme is about delta-MCS, not CQI? Is the intention that the legacy CSI report needs to be configured separately to obtain the valid BLER target for delta-MCS? Also, this FFS should probably also discuss how different BLER values there could be at the UE side.**FFS: How UE determines BLER target (e.g. explicitly indicated by network or linked to a CQI table)** |
| Nokia/NSB | Partly | In general, we are fine with the direction of the proposal. But, we have a concern on mentioning “at least” in the main bullet as companies seem to be not getting the value of case 1 reporting. We think that improved CSI reporting is more crirtical for URLLC operation and even for OLLA operation. Based on our evaluations in last RAN1 meeting, we observed the following. In Figure we show the case when **EP-OLLA (***do not see any big difference on EP or delta-CQI or delta-MCS as all those report a metric based on PDSCH decoding*) is applied on top of the UE’s CSI report. For simplicity, we only showed three CSI report schemes: WB CQI, 2-bit SB CQI, and SINR-STD reporting. For the WB CQI and 2-bit SB CQI schemes, **it is observed that the achieved BLER is significantly reduced, i.e. from around 10% without OLLA down to around the 10-3-10-4 interval**. However, **this does not necessarily translates into a latency improvement as very high OLLA offsets are sometimes needed resulting in too-conservative MCS selection and high queuing delay/PRB load due to low spectral efficiency (**Figure – right). This is not the case for SINR std scheme, as **the performance without EP-OLLA is already pretty decent (approximately 3E-5).** For this reason, it is concluded that OLLA enhancements on their own are not sufficient to deal with very bursty/unpredictable conditions, i.e. OLLA requires a certain level of accuracy of the UE’s CQI report e.g. as provided by new reporting quantities such as Worst-M and SINR std.This was our observation “***OLLA enhancements for URLLC are on their own not sufficient to deal with the problem of very bursty/unpredictable interference conditions. Accurate UE CQI reports, e.g. as provided by New reporting quantities such as Worst-M and SINR std., are still required for OLLA to provide benefits***.”We are not objecting to the direction on delta MCS if the background CSI reporting is accurate enough. Otherwise, we are doing something not useful. Please see our suggestion below in green. FL proposal 8.3-1: Support at least one of the following for CSI enhancements for IIoT/URLLC:~~If supported, the~~ * A new metric based on network configured channel and interference measurement interval:
	+ minimum CQI value at least in frequency domain and time domain ~~(“worst-M CQI”)~~.
	+ FFS: Definition with multiple channel and interference measurement instances within time interval
* ~~For~~ 3-bits differential subband CQI (for increasing granularity of subband CQI) ~~do not further consider 4-bits subband CQI~~.
* ~~If~~ Reporting with CQI-only update ~~is supported~~:
	+ Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).
		- Note: this does not preclude use of minimum CQI value ~~new report based on configured channel and interference measurement, if supported~~.
	+ FFS: Support shorter CSI computation time compared to R16.
		- FFS: how much reduction of CSI computation time is possible
		- ~~Target “CSI computation delay requirement 1” for subband report in which only CQI is updated.~~

If one of the above schemes is supported for CSI feedback enhancement for URLLC, ~~If supported, for the~~ support reporting of delta-~~CQI/~~MCS:* + Report consists of delta-MCS for a TB received with MCS index IMCS:
		- delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.
		- FFS: How UE determines BLER target (e.g. explicitly indicated by network or linked to a CQI table)
	+ FFS: Number of bits for delta-MCS report
	+ FFS: whether delta-MCS is reported (Option 1) jointly with HARQ-ACK codebook or (Option 2) separately from HARQ-ACK codebook.
 |
| Intel | With updates | We can accept this combo of the schemes for further consideration, if the “minimum CQI” is generalized to other filtering schemes.* **A new metric based on network configured channel and interference measurement interval:**
	+ **~~minimum~~ CQI value corresponding to a specified processing of the measurements at least in frequency domain and time domain ~~(“worst-M CQI”)~~.**
	+ **FFS: Definition with multiple channel and interference measurement instances within time interval, and the processing function(s) (e.g. minimum, mean, std dev etc.)**

We think that if the enhanced granularity of sub-band reporting is introduced, then the minimum CQI can already be possible at gNB side. In that sense, the minimum CQI on its own is just a compression scheme for PUCCH overhead.The “Note” for CQI-only update should be removed to not make cross-dependency with the first bullet.BTW, we’ve obtained simulation results for 10x longer operation time to compare baseline, Case 1-1, Case 2-3 to show that there is no confidence issue when looking at 1e-5 point, as was argued by some companies: |
| Futurewei | With updates | This proposal in its current form is not acceptable to us. This proposal ignores the performance evaluation results of multiple schemes: the interference statsitcs scheme with the highest performance gain is proposed to be eliminated, while Case 2-3 with little to none performance gain, and in some cases even performance loss, is proposed to be supported. As we commented previously, we have conducted performance evaluations for Case 1-1 (Statistical CSI/SINR), Case 1-3 (interference statistics), Case 1-5 (CSI based on worst IMR occasion), and Case 1-6 (Worst-M CQI), and our performance evaluation results show that performance of Case 1-3 is the best among the four schemes, with significant performance gain (up to 29%) over the other schemes. We also compared the performance of Case 1-3 to gNB-implementation-based scheme, and our results show a performance gain of 76% over the gNB-implementation-based scheme. The reporting overhead of Case 1-3 is low since its reporting period can be much longer than the CQI reporting period (e.g., 20 times of the CQI reporting period). Case 1-3 does not requires the UE to report “explicit” or “absolute” interference level that it measures. What the UE reports is the variance/standard deviation of its measured interference, which needs to be measured anyway by the UE based on its assigned CSI-IM or NZP CSI-RS.Regarding Case 2-3, four companies have provided performance evaluation results: Intel, InterDigital, Qualcomm, and ZTE. * Out of the two cases simulated by Intel, one shows no performance gain and one shows performance loss.
* Out of the nine cases simulated by InterDigital, six show little to none performance gain and three show performance loss.
* Out of the two cases simulated by Qualcomm, only RU savings in the 2nd TX are observed. But as Intel commented previously, for URLLC, the chance of 2nd TX is very low and the RU savings in the 2nd TX will not translate to noticeable gains in satisfied UE ratio.
* ZTE’s results show some performance gain. However, it seems the results are questionable. First, the RU level seems too low, which is just 1.9%-2.3% in many cases. Second, as commented by companies during GTW session, in one case, the result show that with 3-bit delta SINR for retransmission, the satisfied UE ratio is increased from 50% to 94%, which seems unrealistic.

Regarding minimum CQI, in addition to the fact that its performance is much worse than Case 1-3 as shown in our performance evaluation results, we have similar view to Intel that with increasing granularity of subband CQI (e.g., 4-bit differential subband CQI), the minimum CQI will be straightforwardly available at the gNB. As a compromise and for progress, we can support Intel’s updates on the first bullet with some modifications (in green) as follows:* **A new metric based on network configured multiple channel and/or interference measurement instances within a time interval:**
	+ **~~minimum~~ ~~CQI value~~ The new metric is corresponding to a specified processing of the measurements at least in frequency domain and time domain ~~(“worst-M CQI”)~~.**
	+ **FFS: Definition with multiple channel and/or interference measurement instances within time interval, and the processing function(s) (e.g. minimum, mean, std dev etc.)**
 |
| Samsung |  | The main problem with the proposal is that it keeps most of Case-1 open when there is nothing new to discuss/learn for any Case-1 proposal - all information is known. Arguments and opinions remained about same for the last two meetings – there is no basis to expect that will drastically change over the summer. To stop “kicking the can down the road”, it will be good to conclude on the Case-1 proposals at this meeting (to also reduce a possibility of down-scoping considerations at the next RANP). Case-2 alone is enough to take the rest of CSI-related portion of the URLLC TUs for the next 3 meetings. Otherwise, no major issue. For differential sub-band CQI since, if supported, the size will be up to the gNB configuration - it is strange to preclude 4 bits. For the CSI computation time, the FFS should be kept – we definitively know that any computation time reduction can only be a trivial one. |
| Moderator |  | @vivo, Huawei: Thanks – I think adding this FFS is reasonable for min CQI.@LG: Thanks for support. For delta-MCS appended to HARQ-ACK codebook, in my understanding this is still in scope but we can discuss later if there is impact to HARQ-ACK.@HW/HiSi: For 3-bits, yes, the reason is overhead. I am trying to make each scheme more acceptable to the group, and minimize number of options that are configurable. For the partial CQI update, we can try a different wording but my understanding is that UE vendors are not ready to commit to any (non-zero) reduction at this point. For the delta-MCS, I do not understand what the issue is. What does “target BLER used for the scheduled TB” mean? As this does not seem to be specifiable, how can we incorporate this into an agreement? Also, what is the alternative to referring to IMCS?@Nokia/NSB: what you suggest could be possible, it would be good to hear other companies’ views on this.@Intel: it seems that your suggestion would essentially correspond to supporting all the schemes and selecting by configuration. However, I doubt this is acceptable to others since we agreed to downselect at the last meeting. OK to fix the note in CQI-only update by stating “if supported”. Regarding min CQI, I don’t quite agree that it would be redundant since the overhead price with increased granularity (higher than R16) may be unacceptable at least in certain scenarios.@Futurewei: regarding your suggestion for first bullet, same answer as for Intel (your version would re-add all the schemes).@Samsung: Agree it would be good to conclude at this meeting. |
| DOCOMO | Yes | We are supportive for the proposal but share the same view as Samsung. It would be necessary to narrow down the candidates in Case 1 more in this meeting. Case 2 alone has enough discussion points for the remaining meetings. |
| CATT |  | We also think it is necessary to narrow down Case 1 options. In addition, for reporting with CQI-only update, we think shorter CSI computation time has to be supported since otherwise there is no benefit. So the FFS highlighted in yellow should be removed if reporting with CQI-only update is kept.* **~~If~~ Reporting with CQI-only update ~~is supported~~:**
	+ **Use existing reporting quantities (i.e. all CSI reports are self-contained as in R16).**
		- **Note: this does not preclude use of minimum CQI value ~~new report based on configured channel and interference measurement, if supported~~.**
	+ **~~FFS:~~ Support shorter CSI computation time compared to R16.**
		- **FFS: how much reduction of CSI computation time is possible**
		- **~~Target “CSI computation delay requirement 1” for subband report in which only CQI is updated.~~**
 |
| Lenovo, Motorola Mobility |  | 1. agree with Samsung on number of bits for subband CQI likely to be configurable.2. proposal text (as is) seems to need some clarification [purple]:* **A new metric based on network configured channel and interference measurement interval:**
	+ **minimum CQI value at least in frequency domain and time domain ~~(“worst-M CQI”)~~.**
	+ **FFS: Definition [of what?] with multiple channel and interference measurement instances within time interval**

a. the relation between the minimum CQI value & the new metric needs clarification: e.g., the new metric is based on a minimum CQI valueb. FFS: definition “of the new metric”c. “time interval” is “measurement interval”?maybe an example of the updated text can be as follows:* **A new metric based on network configured channel and interference measurement interval:**
	+ **The metric is based on a minimum CQI value at least in frequency domain and time domain of the measurement interval ~~(“worst-M CQI”)~~.**
	+ **FFS: Definition of the new metric with multiple channel and interference measurement instances within ~~time~~ the measurment interval**
 |
| QC | Yes in general | We are supportive of FL’s proposal in general. One high level comment: we don’t see case 1 and case 2 are mutually exclusive, because the measaurement source for them are different. One is based on CSI-RS, the other is based on PDSCH decoding. Therefore, we suggest to support two schemes in Rel-17, one for case 1 and one for case 2. This comment is sort of related to Nokia’s comment. But we have oppositve view with Nokia, we think case 2 is more important than case 1. Hence we are not OK to conditioning the supporting of case 2 on supporting of case 1. Supporting both in parallel is fine to us. Therefore, we suggest change the “**Support at least one of the following for CSI enhancements for IIoT/URLLC:**” to “**In the following candidate schemes,** **support one scheme in case 1 and one scheme in case 2 for CSI enhancement for IIOT/URLLC**”. One low level comment to “**Support shorter CSI computation time compared to R16**”. Like we already commented multiple times, before careful study on the possibility of CSI processing time reduction, we cannot commit to support shorter CSI processing time, as a UE vendor (By the weay, I suggest companies read other companies comments). **Therefore, we will object the “CQI-only” scheme if the FFS on processing time is removed, due to no concrete study results available to demonstrate the feasibility of the processing time reduction.** If any company has a number for CSI processing time, please let us know that the number is obtained based on software simulation of CSI processing timeline, or based on measurement of time use real hardware. What is the pineline assumed for UE CSI processing? What is the CPU assumption? What is the hardware chipset used for measurement. What is the clock used in this simulation/measurement? We will like to verify the number with our product team, before we can agree on supporting shorter CSI processing time. One editorial comment: for the 4 schemes, maybe add note or a few words in a bracket to indicate each scheme is for case 1 or case 2.  |
| ZTE | Yes | We are fine with the proposal. We share the same view that case 1 and case 2 should not be mutually exclusive because they are totally different paths for the CSI enhancement. We would like to clarify something on the case 2 report in our simulation. We can see the delta SINR based on NACK has a best performance gain in terms of satisfied UE(93.81% over 49.52%). As commented in the second round discussion, delta SINR is directly used for the network to adjust the backoff for OLLA. In case NACK happens, the negative delta SINR makes the backoff be reduced significantly. It leads to the network performs quite conservative scheduling for a long time, even after a new CSI report. In this case, the BLER of the initial is quite low at the cost of a bit higher resource consumption.For the RU, we need to consider this to identify the benefit the proposed method. So we just need to compare the RU between different methods or between the new method and the baseline. Regarding the RU level in the simulation, we don’t think it is very important since the network use the same method for resource allocation in the simulation anyway. |
| Apple |  | We don’t feel comfortable to commit the support of at least one while we don’t know which one will be selected. Also agree with QC on processing time, it is not good to reopen the discussion on CSI processing timeline, which was hotly debated in Rel-15. The following needs to be removed:* + **FFS: Support shorter CSI computation time compared to R16.**
		- **FFS: how much reduction of CSI computation time is possible**
 |
| Ericsson | No | Unfortunately we fail to see that this combo proposal is putting RAN1 in a better position to finish the work. There is no evidence that any of the 4 schemes gives convincing performance benefits and have universal support from all companies. Thus it’s premature to declare that at least one will be supported. It can only be phrased as “Focus the study on …”, i.e., similar situation as last meeting.The only thing achieved by the proposal is, for the ‘new metric’ bullet, the four schemes are down-selected to one. We fail to see the justification of this down-selection result. According to response to FL proposal 8.2-1, the poll is as follows for “Worst-M CQI”.Yes (4): QC, DOCOMO, ZTE, NokiaNo (8): FutureWei, Samsung, Vivo, HW/HiSi, Sony, Oppo, EricssonUnclear (1): Intel We are not convinced that “Worst-M CQI” should be declared winner of the down-selection via this proposal. |
| Vivo2 |  | Thanks a gain FL for the hard work on this difficult topic. After a second thought, we tend to agree with several commets made by companies above, given the divergent support from companies and the fact that some schemes are not stable (further refinement needed), and there seems no very clear advantage from any of the schemes compared to other schemes, it seem pre-mature to commit now that we will support one scheme. Imagine if companies do not convince each other in next meeting tehnically, we do not want to be forced to select one scheme just because we have this agreement. Therefore we support Ericsson’s suggestion to change the main bullet as “RAN1 to focus on the following for CSI enhancements for IIoT/URLLC” |
| Spreadtrum | Yes partially  | We basically support the proposal, except one comment for shorter CSI processing time. From our perspective, it does not make sense to reduce CSI computation time based on Case 1-11. It has been detabe many times in past releases. Clearly, CSI processing time basically the most difficult point of implementation. Before clear and elaborate analysis and evalution, we don't want the FFS point here. Anyway, it is an FFS, if any company want this point, we can discuss it next meeting.  |
| Nokia/NSB2 |  | This discussion is not easy over email as different opinions or interpretations on what is best for URLLC are raised. Overall, we have many technical concerns on several schemes listed in the FL proposal, but we are not trying to list them to avoid further deadlock. Few comments to companies responded after Nokia comments. @Intel, FW >> the update you suggest makes the first bullet too broad as it is trying to contain multiple reporting metrics. Hard to see any progress by doing that. @Intel and FW >> Intel mentioned, “if the enhanced granularity of sub-band reporting is introduced, then the minimum CQI can already be possible at gNB side”, **if we make the sub-band CQI reporting as 4 bits and limit reporting to the worse sub-band or worse M sub-bands,** I would agree with your observation. Based on further analysis on overhead, we could try to have something like that in the next meeting. Overall, worse-M is the easiest scheme to introduce to help URLLC. @Intel >> The last comment on Case 1-1 and 2-3 was not fully clear. But, as I understand, you seems to be agreeing with our observation on using case 2 without a good background CSI reporting enhancement. @FW>> agree with your observation on Case 2-3. @SS, DCM >> We generally agree to down-select to one scheme on case 1 and there is no much time left in Rel-17. Lenovo >> some answers for you. 1. New metric is the minimum CQI.
2. Not clear the question. Our understanding is new metric is minimum CQI. Nothing is FFS there.
3. Interval is anyways in time domain. That is how existing measurement restrictions are applied.

Overall your update may be not critical but ok with clarifying the new metric is min CQI to avoid confusion. @QC, ZTE >> A similar view on supporting case 1 and 2 both. Priority should not be an issue if we support both. Otherwise, we prefer case-1 due to the technical reasoning we mentioned and also highlighted by Intel, FW and some others. CATT, QC, Apple >> agree with QC and Apple and second bullet under CQI-only should be further studied. We suggest to keep the FFS. @E/// >> On the progress, further study does not help with multiple schemes. Reporting a minimum CQI considering the required lower overhead (unlike sub-band CQI) while also capturing time and frequency domain interference is required at the gNB side. Please also note that best-M already there in LTE, and this worse or best is nothing new to 3GPP. We expect to proceed with a simpler approach that a majority can accept.  |
| HW/HiSi 2 |  | **Thanks a lot for the feedback and please find further on my replies.****For the main bullet, we share the view with Ericcson, vivo and Apple that we are not comfortable with agreeing on the support of at least scheme at this stage.****We would prefer to update the main-bullet as vivo suggested: “***RAN1 to focus on the following for CSI enhancements for IIoT/URLLC***”**Please see below feedback on the Moderator’s comments and further thoughts how we could update proposals for the individual schemes:**For the sub-band CQI** From moderator: “*For 3-bits, yes, the reason is overhead. I am trying to make each scheme more acceptable to the group, and minimize number of options that are configurable*.”Thank you for clarifying the intention. We agree with Samsung and Lenovo and also think that overhead is not an issue since it can be configured by the gNB. Also, the main motivation is to improve the accuracy of sub-band CQI, and here the 4-bits CQI is better. We propose to update the proposal:***RRC configuration of enhanced sub-band reporting, gNB can configure 3 bits differential subband CQI or 4 bits sub-band CQI (for increasing the granularity of the sub-band CQI*****For partial CQI update**From moderator: “*For the partial CQI update, we can try a different wording but my understanding is that UE vendors are not ready to commit to any (non-zero) reduction at this point.”* Thank you for being open for a further discussion. We think RAN1 needs to reduce the CSI computation time. The CSI computation time, especially for sub-band CQI is very long. For 30 kHz, the low latency CSI delay is 10 OS but the sub band-CQI is 40 OS. Some companies raised a concern that re-doing the CSI delay discussion from Rel-15 would become lengthy. We don’t think so. Thanks to the extensive work we have spent in Rel-15 we can re-use most of it.For URLLC sub-band CQI should be used mostly and this currently follows delay requirement 2. The conditions that have been studied in Rel-15 to achieve the fast legacy delay requirement 1, could be re-used for partial CQI update and could be applied to accelerate the sub-band CQI reports, i.e. single CSI report, L = 0 CPU occupation, and single CSI resource can be re-used. The only differences are: sub-band report instead of wideband report, and PMI/RI don't need to be updated at the same time (which still is required for the fast CQI for up to 4 CSI-RS ports).It should go rather quickly to evaluate the processing time gain for this. If RI/PMI do not need to be updated at the same time, as shown e.g. in the Oppo paper, the complexity can go down from *O*(196) to *O*(1). This gives a very good indication about the feasibility to reduce the computation time. If chipset vendors still have concerns how much the processing time can be reduced, we think it can should studied further for delay requirement 2 and the conditions mentioned above could be taken into account.**Based on the above reasoning and our previous discussions, the main bullet for partial CQI should not contain a FFS on if the CSI processing be shall be reduced.** This is fundamental for this scheme and would throw us back too much in the discussion otherwise. We should agree on that CSI processing time shall be reduced and then have an FFS how it can be achieved and how much reduction is feasible. We should also define a clear target how much reduction is needed to make this scheme attractive. This will set a good focus for the continued study. Then, based on the outcome of this study, RAN1 can still decide if this scheme should be supported or not. But we think RAN1 should really look into reduced CSI processing time, the current values for delay requirement 2 are too conservative. We should not just sit back and say that it cannot be improved. Therefore, we are making the following updated proposal: * **~~FFS:~~ Support shorter CSI computation time compared to R16.**
	+ **Strive for a processing time reduction of delay requirement 2**
	+ **FFS: how much reduction of CSI computation time is possible**
	+ **FFS: further conditions can be considered to be re-used from the Rel-15 discussion to achieve low latency CSI requirement 1.**

**For the delta-MCS report****From the moderator**” *For the delta-MCS, I do not understand what the issue is. What does “target BLER used for the scheduled TB” mean? As this does not seem to be specifiable, how can we incorporate this into an agreement? Also, what is the alternative to referring to IMCS*?”The problem with the currently proposed bullet: * delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.

It may only be feasible under the assumption that the gNB applies directly the MCS that is obtained from the UE report. Otherwise, too many bits would be required as I try to explain in the following example: * Assume that the UE is calculating the MCS based on a low target BLER, e.g. 1e-5. But the gNB wants to schedule with a higher BLER, e.g. in an initial transmission, to achieve a better spectral efficiency. For example the UE calculates MCS=8 for the BLER 1e-5, but the gNB schedules the TB with IMCS=15.
* If the channel conditions have not changed during the PDSCH reception, the UE would again obtain MCS=8. Using the IMCS as reference, the UE would report: delta-MCS=IMCS-MCS@UE =15-8=7. That means delta-MCS=7 would mean “do no change of MCS for the TB”
* If the channel conditions have become better during the next PDSCH reception, the UE would obtain MCS=9. Using the IMCS as reference, the UE would report: delta-MCS=IMCS-MCS@UE =15-9=6. And similar, if the conditions have become worse, the UE would obtain MCS=7 and report delta-MCS=15-7=8.

From the above example it can be seen that delta-MCS=6 means “go up one MCS-step, “7” would mean “no change” and “8” would mean “go down one MCS-step”. This requires a substantial number of bits in order to provide the gNB useful information in the delta-MCS report. And even if the MCS offset at the gNB would be just one step, then also one additional bit is already required in the delta-MCS report.A “MCS mismatch” issue may always arise when the gNB can use a different MCS then what would be the outcome of the MCS calculation at the UE side based for a certain target BLER. **Therefore, we would like to discuss firstly, if the UE can use any BLER target for MCS calculation or a limited set of BLER targets and if the gNB has to follow that**. The outcome of this discussion will then impact how to define the reference for the delta-MCS. One possibility, if the MCS mismatch is avoided somehow, would be to use the IMCS directly. The other option, which could be simpler for UE implementation, is to allow a mismatch between selected and reported MCS and to let the UE compensate for this in its delta-MCS report. It has very hard to discuss this by email comments and we would like to have a deeper technical discussion on it with other companies, therefore, we propose to have the following FFS.* **~~If supported, for the~~ Reporting of delta-~~CQI/~~MCS:**
	+ **FFS: For TB scheduling, shall gNB apply the MCS value that was the outcome from UE channel measurement based on PDSCH decoding for the target BLER assumed at the UE.**
	+ **FFS: how to calculate the delta-MCS, e.g.**
		- **Delta-MCS=IMCS-MCSBLER@UE**
		- **Delta-MCS=IMCS-MCSoffset-MCSBLER@UE**
		- **Note: IMCS is the MCS of the scheduled TB, MCSBLER@UE is the MCS obtained at the UE based on the assumed target BLER, MCSoffset is the offset between MCS of the scheduled TB and the MCS obtained from the UE based on the assumed BLER**
 |

# Topic #3: New reporting (Case 2)

## Summary of issues for Topic #3

At RAN1#105, it was agreed to focus study of Case 2 new reporting to delta-MCS/CQI. Several companies provided evaluation results for this scheme.

Evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| ZTE [5] | Case 2-3(Delta SINR)Initial transmission | AR/VR | 61% satisfied UEs [50%] 2.3% RU [1.9%] |
| ZTE [5] | Case 2-3Retransmission: Delta SINR (3-bit) | AR/VR | 94% satisfied Ues [50%]33% RU [1.9%] |
| ZTE [5] | Case 2-3Retransmission: Delta MCS (3-bit) | AR/VR | 60% satisfied Ues [50%]1.9% RU [1.9%] |
| Intel [12] | Case 2-3(Delta SINR)Initial transmission(IMR for actual loading) | Factory | 42% satisfied Ues [42%]6.4% RU [6.3%] |
| Intel [12] | Case 2-3(Delta SINR)Initial transmission(IMR for full loading) | Factory | 35% satisfied Ues [37%]27% RU [24%] |
| Qualcomm [16] | Case 2-3Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 20 URLLC Ues) | 100% satisfied Ues [100%]3471 RBs for 2nd Tx [5255] |
| Qualcomm [16] | Case 2-3Retransmission: Report CQI/MCS | AR/VR (mixed traffic, 100 URLLC Ues) | 100% satisfied Ues [100%]5878 RBs for 2nd Tx [7545] |
| InterDigital [18] | Case 2-3Initial transmission: Report delta-MCS (1 bit) | AR/VR(20 Ues /cell) | 99% satisfied Ues [99%] 7.0 RU [7.0 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Initial transmission: Report delta-MCS (1 bit) | Factory(20 Ues /cell) | 100% satisfied Ues [100%] 3.2 RU [3.4 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Initial transmission: Report delta-MCS (1 bit) | Factory(40 Ues /cell) | 97% satisfied Ues [99%] 4.3 RU [3.4 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (1 bit) | AR/VR(20 Ues /cell) | 97% satisfied Ues [99%] 7.0 RU [7.0 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (1 bit) | Factory(20 Ues /cell) | 100% satisfied Ues [100%] 3.5 RU [3.4 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (1 bit) | Factory(40 Ues /cell) | 100% satisfied Ues [99%] 4.9 RU [3.4 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (5 bits) | AR/VR(20 Ues /cell) | 93% satisfied Ues [99%] 7.0 RU [7.0 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (5 bits) | Factory(20 Ues /cell) | 100% satisfied Ues [100%] 3.4 RU [3.4 RU]Report periodicity 20 ms |
| InterDigital [18] | Case 2-3Retransmission: Report delta-MCS (5 bits) | Factory(40 Ues /cell) | 100% satisfied Ues [99%] 4.7 RU [3.4 RU]Report periodicity 20 ms |

The agreement from RAN1#104b-e states that delta-MCS/CQI is to be studied but there is no agreement to support yet. Based on the submitted input, the support from companies can be summarized as follows (some companies that did not express clear preference are not listed).

**Issue #3-1**: Support Delta-CQI/MCS reporting?

Supportive: Ericsson [3], Spreadtrum [7], CATT [8], Qualcomm [10], OPPO [11], (Sony [14]), Samsung [16], InterDigital [18], Nokia [19]

Concerns: Futurewei [2], Huawei [4], Intel [12]

* Need to better understand how it helps gNB improve MCS selection before deciding [2]
* Need to agree on supporting A-CSI on PUCCH first [4]
* Uncertain performance benefits at expense of high spec impact [12]

The agreement from RAN1#104b-e states that delta-MCS or delta-CQI can be studied. A number of companies provided analysis on which of the two options is preferable, and further on how to determine the reference MCS or CQI for the “delta” signaling.

**Issue #3-2**: Whether to report delta-MCS or delta-CQI?

* Delta-MCS: Ericsson [3], CATT [8], Qualcomm [10], OPPO [11], Sony [14], Quectel [15], Samsung [16], InterDigital [18]
	+ Reporting is based on actual transmission with specific MCS [3]
	+ MCS granularity is finer than CQI [3][8]
	+ No additional overhead of measurement resource or computation time budget [11]
	+ Less computation at the UE (CQI would require conversion) [14][16]
	+ Delta-CQI would depend on scheduler implementation [15]
	+ Definition: BLER with index Imcs+Dmcs is smaller than/equal to BLER of MCS table for TB [16].
* Delta-CQI: Huawei [4]
	+ Minimize specification impact [4]

**Issue #3-3:** Reference CQI/MCS

* Scheduled MCS: CATT [8], Qualcomm [10], OPPO [11], Samsung [16], InterDigital [18]
	+ No error propagation issue that would occur if it would be referred to previous report [11]
* Do not use MCS of PDSCH as reference for delta-CQI/MCS report: Huawei [4]
	+ Due to mismatch between BLER as previous CQI report and target BLER of the PDSCH (if BLER of previous CQI report is used as target BLER for reporting)

A few companies discuss how the UE determines the target BLER for the determination of delta-MCS/CQI:

**Issue #3-4:** Target BLER

* Semi-static configuration: Ericsson [3], Sony [14] (per SPS config)
	+ Using values from configured CQI tables (1e-1 or 1e-5) not flexible enough for gNB [3]
* Dynamically from RNTI of the DL assignment: Sony [14]
* Same BLER as previous CQI report: Huawei [4] (“option 1”)
* Tied to the MCS table used for PDSCH: Samsung [16]

The following issues (3-5/3-6/3-7) relate to triggering and reporting aspects. A first question (3-5) is on whether the new report should be transmitted as part of the HARQ-ACK codebook or in a separate resource. In case the new report would be transmitted in a separate resource, the issue of how to trigger (and provide resource) needs to be considered (3-6). In addition, many companies discussed the issue of how to control the amount of reporting, which exists regardless of what is decided for the reporting resource.

**Issue #3-5:** Reporting resource

* Within updated HARQ-ACK codebook: Ericsson [3], Spreadtrum [7], (CATT [8]), Apple [13], Samsung [16]
	+ No need to send earlier than HARQ-ACK: Spreadtrum [7]
	+ Type 2 codebook only (too much information otherwise in Type 1): Ericsson [3]
	+ Avoid modification to R16 HARQ-ACK codebook construction [16]
* Outside HARQ-ACK codebook: Ericsson [3], (Huawei [4]), (Spreadtrum [7]) (CATT [8]), LG [17], Nokia [19] (?)
	+ May require less resources (control when and how often to report) [3]
	+ Reuse current CSI framework [17]
	+ On PUCCH only: Ericsson [3], Huawei [4]
	+ Requires mapping to a reference PDSCH: Ericsson [3], LG [17]
	+ On semi-statically configured resource: (CATT [8])

**Issue #3-6:** Triggering (in case it is outside of HARQ-ACK codebook):

* From DL DCI with new field: Huawei [4], Spreadtrum [7]
* Implicit from DL DCI: (CATT [8])
* Semi-static: (CATT [8])

**Issue #3-7**: Whether to report for every PDSCH, applicable conditions

* High-priority codebook [3][19], SPS [3], HARQ process [19], configured TBS [19], MCS threshold [19]
* Multiple PDSCH to one delta-MCS/CQI to reduce overhead [7]
* May use time window [8]
* Per-CC reporting [8]
* Dynamically indicated from RNTI of DL assignment [14]
* May take an average/filter from multiple PDSCHs [14], [16] (type 1 codebook)
* gNB indicate number of TBs for which UE provides delta-MCS value [16]
* Should not report for every ACK/NACK position in codebook [21]

Several companies discuss the number of bits and granularity of the new report:

**Issue #3-8:** Number of bits / mapping

* 1 additional bit [18][21]
* 2 bits including HARQ-ACK: [3][10]([16])
* 2 bits [8]
* Mapping depends on scheduled MCS range [11]
* Number of bits/mapping provided by higher layers: Samsung [16]

A few companies discuss whether the new report should target OLLA or retransmission:

**Issue #3-9**: Report for initial transmission, retransmission or both?

* At least for initial transmission (for OLLA): Nokia [19], Mediatek [21]
* Multi-level NACK (for retransmission) more important than multi-level ACK: ZTE [5]

A few companies discuss testability and definition aspects:

**Issue #3-10:** Testability, derivation of delta-CQI/MCS

* How to generate delta-MCS up to UE implementation (RAN4 tests to check that delta-MCS varies properly with varying SINR at fixed MCS): Ericsson [3]
* Delta CQI/MCS can be derived by UE implementation based on the ratio of failed parity checks in LDPC decoding. Throughput test and BLER test can be defined in RAN4: Qualcomm [10]
* Discuss exact method for deriving delta-CQI/MCS as it is related to possible RAN4 test cases: Nokia [19]

Other proposals/issues

* Both positive and negative delta-MCS (for positive ACK) to enable convergence: Ericsson [3]
* PDSCH is measurement resource: Spreadtrum [7] (moderator note: already agreed)
* May use multiple measurement resources: CATT [8]
* Support configuration of two MCS tables for PDSCH/PUSCH and indication of an MCS table by PI field in the DCI format: Samsung [16]
* Study impact on UE processing timeline [21][22], codebook construction procedure [21]
* Study impact of PDSCH symbols punctured or rate-matched [22], retransmissions [22]

## Observations for Topic #3

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

From the three first issues, it seems that there is majority view on the following aspects:

* The new report type should be supported;
* Delta-MCS is preferable to delta-CQI;
* The reference MCS for delta-MCS is the MCS applied to the scheduled PDSCH from which report is derived.

Moderator suggestion is to agree on the following proposal that includes a definition of delta-MCS. The definition suggested in [16] is used as a starting point (with some modifications given that how to determine BLER target needs to be further discussed).

**FL proposal 9.1-1**: **Support reporting of delta-MCS for a TB received with MCS index IMCS:**

* **delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
* **FFS: How to determine BLER target.**

For the issues related to reporting resource (within HARQ-ACK codebook or in separate resource), there does not seem to be clear majority in favor of either option at this point. Moderator suggestion is to gather additional input on this issue during this meeting.

**FL proposal 9.1-2**: **For reporting of delta-MCS, select between the two following options for the resource:**

* **Option 1: delta-MCS is reported as part of an extended HARQ-ACK codebook**
* **Option 2: delta-MCS is reported as a CSI report separate from HARQ-ACK codebook**
	+ **FFS: Type of resource (e.g. PUCCH or higher layers)**
	+ **Note: this does not preclude that the CSI report and HARQ-ACK codebook are multiplexed in same resource per multiplexing rules.**

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

TBD

**Question 3-1**: Please provide feedback if you would like to either (a) make correction in this moderator summary (such as evaluation results or company position) or (b) add your company position relative to the schemes listed in the above.

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

**Question 3-2**: Please indicate if FL proposal 9.1-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | This is just a short answer due to lack of time before the GTW. Hopefully we can have a more detailed discussion on this scheme after the GTW.We don’t think that the UE needs to (or should) be made aware of the target BLER target is used by the gNB scheduler. The gNB scheduler can basically select any target BLER, and it can also change it dynamically, e.g. for initial TX and re-TX or when serving eMBB and URLLC. Therefore, the UE algorithms to calculate the CQI could be become too complicated, since the UE would be required for to be able to calculate the best CQI for an infinite set of BLER values. Besides the implementation impact, there is also a testing impact and a possible constraint on the gNB scheduling flexibility. We think that the UE should base the CQI calculation on the BLER values that are defined in Rel-16. This will keep the UE complexity lower. We should start with this assumption and then discuss the consequences, for example the required bitwidth for the delta-MCS report. |
| Nokia | No | We do not see any difference in MCS or CQI used in the reporting. It is just a report of SE value (with code rate and modulation). In that sense, reporting framework should first be discussed rather than the deciding CQI or MCS.  |
| Samsung | Yes | Delta MCS is simpler as there is a reference MCS (of the received TB). Although the gNB can vary the BLER per TB, there is no issue (otherwise, the CQI provided for a fixed 10% (or 0.001%) BLER wouldn’t work). A delta\_MCS of 2-3 bits and a granularity of delta\_MCS of ~3 entries from the MCS table can capture 2-3 orders of magnitude for BLER variations (no need/benefit/feasibility for delta\_MCS to have a granularity of a single MCS table entry).  |
| Ericsson | Yes | In first bullet of the proposal, add: “delta-MCS” can be positive, negative, or zero” |
| Futurewei | No | Based on the performance evaluation results provided by multiple companies, there is little to none performance gain of Case 2-3 over baseline, and in some cases it results in performance loss. We should not support a scheme that doest not provide performance gain.  |
| QC | YES | Regarding simulation results, in this meeting, in total, 4 companies (ZTE/QC/Interdigital/Intel) submitted simulation results for case 2. ZTE/QC/Interdigital results show gains. Even Intel result actually show gain of case 2. I don’t see what is the foundation for the comment “case 2 has little to none performance gain”. Let’s look at Intel’s result. The following figure is copy-and-pasted from Intel tdoc R1-2104900. Based on the information in the tdoc, the figure is the BLER of “single-shot scheduling” – meaning it is BLER of 1st transmission, not residual BLER after retransmission. For many URLLC services, the BLER of first Tx is not 10^-5 but actually lower such as 10^-4, considering the latency requirements allowes reTx to get residual BLER of 10^-5. In the following figure, if we check the 10^-4 BLER, 90% UE can achieve 10^-4 BLER with delta MCS enabled (showed in the light blue curve), while only 80% of the UE can achieve 10^-4 with baseline (dark blue). **Isn’t this results show that there is a 10% performance improvement with delta MCS, at least at 10^-4 BLER target**? For the curves in the region of 10^-5 ~ 10^-6 region, I would doubt the accuracy of the curves and not trusting them, because the # simulation points may not be enough to show an accurate results – the coarse steps of the curves in 10^-5 ~ 10^-6 region indeed suggest the curve may not be accurate.  |
| Moderator |  | @Sony, Samsung, Ericsson, QC: Thanks for support.@HW/HiSi: I am not sure how the UE could derive any delta-MCS/CQI without assuming a target BLER? Also note that there is “FFS: how to determine target BLER”. This FFS includes possibility of using a target BLER corresponding to R16 which you suggest.@Nokia: I don’t understand your concern. What do you mean by “reporting framework”? |
| ZTE | Yes with a question | Regarding the metric, our first preference is delta SINR as explained many times because it can directly used for the network to adjust the backoff, which is benefit for the subsequent scheduling even after the gNB gets the new CSI report.For the delta CQI and delta MCS, we think there is no difference. But we have a question on how the network use the report. Does the network just regard the delta/MCS as a new CSI report while the backoff is not affected (i.e., it is only affected by the ACK/NACK feedback)? Or the backoff is adjusted based on the delta MCS/CQI. We think there may be no difference for the scheduling before a new CSI is reported. But after that, things may be different due to the different backoff values. So the answer is useful for us to better understand this case. Thanks. |
| OPPO | Yes |  |
| LG | Yes |  |
| Quectel | Yes | It is too overhead-consuming, if the delta MCS is reported with a granularity of one MCS table entry. We prefer to define a number of MCS entry ranges for delta MCS reporting or just use positive, negative, or zero for the reporting. |
| Intel | No | @QC, by the way we’ve updated results in R1-2105958, showing that Case 1-1 performs better than Case 2-3 in both 1e-5 and 1e-4.Why we say there is no gain in companies results, except ZTE, is by analyzing Moderators table above. It shows -7 to +1% improvement in InterDigital results; 0% improvement in QC results; -3 to 0% improvement in Intel results. In QC results the gain in RU for 2nd retx is shown, which actually translates to < 1% total resource utilization improvement if the probability of 2nd retx is accounted – we don’t believe it justifies the work on Case 2-3.We also don’t think that comparing the performance at 1e-4 while the target for link adaptation was set to 1e-5 is reasonable.Finally, in case at least one retransmission is allowed, the accuracy of knowing channel conditions for ReTX is much less important than the first TX, this was shown in our previous tdocs for RAN1#103-e and RAN1#104-e, where HARQ retransmissions work just fine unoptimized.Overall, we would like to highlight that the decision should be technical and data based, that is why the evaluation results should be seriously taken into consideration. |
| HW/HiSiUpdate 1 | No | We are fine with the main bullet. For the rest, we would like to have a technical discussion firstly.Regarding the first sub-bullet:* In our understanding it implies that the BLER target at the UE, i.e. the target BLER which is the basis for CQI/MCS and delta-MCS calculation based on the PDSCH decoding has to be the same as the target BLER that is used by the scheduler for the TB transmission. Otherwise, the formula cannot work, since the MCS of the TB is based on the BLER for the scheduled PDSCH, whereas the delta-MCS must be based on the BLER that is used for the for the CQI calculation at the UE when decoding the PDSCH. Is this a correct understanding of have we missed something here?
* Is the intention (or implication) of this bullet that for the MCS selection for the TB, the gNB has to follow the target BLER that was underlying for the UE’s CQI/MCS/delta-report when decoding the PDSCH? This would be quite different to Rel-16, where the target BLER at the UE side is based on a certain value (e.g. 10%) but then the gNB can select an MCS corresponding to any target value.
* Depending on the answer to the above question, we think there are several issues we need to address before agreeing before going on with this sub-bullet, e.g. how many bits are acceptable to spend for the delta-MCS report and on what reference to base the delta-MCS (e.g. only on the schedule MCS or is more information needed, can the gNB dynamically change the BLER target rate ?

For the second sub-bullet* Based on the discussion of the first sub-bullet bullet, we are not sure about if it is needed. We would firstly like to discuss the general principles how this scheme shall work, so that everyone is one on the same page.

**FL proposal 9.1-1**: **Support reporting of delta-MCS for a TB received with MCS index IMCS:*** **FFS: MCS selection at the gNB shall be based on the same target BLER that was used at the UE side when obtaining the MCS from the PDSCH decoding**
* **FFS: number of bits for the delta-CQI report**
* **~~delta-MCS is largest value such that BLER of the TB received with MCS index I~~~~MCS~~ ~~+ delta-MCS would be smaller than or equal to a BLER target.~~**

**~~FFS: How to determine BLER target.~~** |
| Nokia2 |  | @moderator >> Reporting framework is discussed in the next proposal. We should first see whether to use HARQ or CSI framework. If we use CSI framework, it makes sense to use CQI. So, we should not worry too much on this proposal for now.  |
| Moderator |  | @ZTE: thanks for the questions. My understanding is that there are different possible ways the network can use the information. So far in the evaluations, companies have used it either to adjust OLLA bias or to adjust the MCS for the retransmission (in case of NACK). Of course, both can be done.@HW/HiSi update 1: Thanks for the questions. Please find answers (by bullet) based on my understandingAs long as both scheduler and UE know what target BLER the UE assumes, the delta-MCS provides useful information. This does not prevent the scheduler to pick a MCS that would result in a different BLER based on its implementation (as today). It may be easier to use (or more accurate) if the BLER that the scheduler wants to achieve is the same as the target BLER the UE assumes for the delta-MCS, but not a hard constraint. Whether the BLER target assumed by UE is e.g. configured semi-statically (explicit or linked to an CSI config) or dynamically is something to discuss in the next step (this is why we have “FFS: how to determine BLER target”). We can add another FFS for the number of bits too.@Nokia2: I think this is independent of whether the report is sent along with HARQ-ACK or in separate resource. Given that there is majority in favor of delta-MCS, I do not see why we should delay progress on this issue. |
| QC2 |  | @Intel, even in your update simulation results, I still read at 10^-4 PER, delta -MCS is 10% better than the baseline. The Ues satisfy 10^-4 PER increased from 80% to 90% (from the dark blue to light blue curve). Can you explain how do you read the other way round?Regarding our simulation on RU for 2nd ReTx, what we simulated is a lightly loaded system. But you need to consider a heavily loaded system. In that case, resource shortage will translate directly to drop of % of Ues satisfying URLLC latency requirements. Unfortunately, directly simulation of heavily loaded system takes too long becomes almost infeasible in practice.  |

**Question 3-3**: Please indicate if FL proposal 9.1-2 is acceptable, and your views on whether Option 1 or Option 2 is preferable.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Sony | Yes |  |
| HW/HiSi | No | In our understanding Option 1 is out of scope. Delta-MCS cannot be part of the extended HARQ-QCK codebook, in this case it should be handled in AI 8.3.1.1 about HARQ enhancements. |
| Nokia | Partly | Generalize the reporting quantity and select first which framework is matching the best. We feel that CSI framework and HARQ framework are both suitable. But using Csi framework may be much easier than introducing a new mechanism.  |
| Samsung | Yes | Prefer option 1. Option 2 does not work in general, is challenging for TDD, may result to duplicated signaling, complicate specifications, and there is no benefit from delta\_MCS if there is no one-to-one mapping of values with TBs (average delta\_MCS is practically useless).  |
| Ericsson | Yes | Regarding Option 1 vs 2: we can accept either. Slightly prefer Option 1 due to simplicity and less standardization effort. |
| Futurewei | No | Please see our previous comment on Proposal 9.1-1. |
| QC | Yes | Open to discuss option 1 vs option 2. But Option 1 is preferred, because option 2 has larger spec impact such as new procedures for UCI multiplexing/UL collision resolution, new procedure to concatenate CSI reports for multiple PDSCHs.  |
| Moderator |  | @Samsung, Ericsson, QC: Thanks for support.@HW/HiSi: In my understanding, Option 1 should not be out of scope (this is about reporting resource and does not have the effect of transforming CSI into HARQ-ACK). |
| ZTE | Yes | Option 1 is preferred since it is simple. Of course, we can also accept option 2. |
| OPPO | Yes | Slightly prefer to Option 1.  |
| LG | No | We share similar view to Huawei/Hisilicon. It should be avoided to change or enhance HARQ-ACK codebook in this AI.  |
| Quectel | Yes | Open to discuss both Option 1 and Option 2. Option 1 is slightly preferred as it may have smaller specification impact. |
| Intel | No | Assuming 9.1-1 needs to be resolved first. |
| HW/HiSi | No | In addition to our previous comment, we think it is too early for this proposal here.We think it would be more efficient to discuss and agree on the general principles and also get a feeling for how many bits would be needed for the delta-MCS. Doesn’t this would give us guidance for the options here? |
| Moderator |  | @HW/HiSi: The proposal is to identify the Options, not to select. The decision on which Option could be based on how many bits would be needed and other considerations. It is important to at least identify the Options otherwise it is difficult to make progress. |

## E-mail discussion (2nd round) for Topic #3

In view of the comments, moderator proposes to agree on the following:

**FL proposal 9.2-1**: **If supported, for the reporting of delta-CQI/MCS**:

* **~~Support reporting~~ Report consists of delta-MCS for a TB received with MCS index IMCS:**
* **delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
* **FFS: How ~~to~~ UE determines BLER target**
* **FFS: Number of bits**

For the issues related to reporting resource (within HARQ-ACK codebook or in separate resource), there does not seem to be clear majority in favor of either option at this point. Moderator suggestion is to gather additional input on this issue during this meeting.

**FL proposal 9.2-2**: **For reporting of delta-MCS (if supported), select between the two following options for the resource:**

* **Option 1: delta-MCS is reported as part of an extended HARQ-ACK codebook**
* **Option 2: delta-MCS is reported as a CSI report separate from HARQ-ACK codebook**
	+ **FFS: Type of resource (e.g. PUCCH or higher layers)**
	+ **Note: this does not preclude that the CSI report and HARQ-ACK codebook are multiplexed in same resource per multiplexing rules.**

**Question 3-4**: Please indicate if FL proposal 9.2-1 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | As we commented previously, based on the performance evaluation results provided by multiple companies, there is little to none performance gain of delta-CQI/MCS over baseline, and in some cases it results in performance loss. We should not support a scheme that does not provide performance gain. |
| Samsung | Yes | Under the assumption that the first FFS does not relate to UE implementation aspects. |
| CATT | Yes |  |
| vivo |  | Based on the evaluation results provided by some companies, there seems no performance gain or quite limited gain for Case 2-3 compared to the baseline. Besides, we need to make comparison between Case 2 schemes and Case 1 schemes before we draw conclusion which one will be supported.On the other hand, it is questionable that how performance gain of Case 2-3 can be achieved without the support of shorter CSI computation time. |
| QC | YES | I suggest companies respect other companies simulation results, when making statement on performance gain/loss. I can not speak for other companies who submitted results. But at least in QC contribution, our system level results show universal gain on RU saving from 22% - 35% for 2nd transmission. That can translate to 20%-30% 2nd transmission satisfaction ratio improvement. For URLLC service allowes 2nd Rx, this is huge improvement. @Intel, even in your update simulation results, I still read at 10^-4 PER, delta -MCS is 10% better than the baseline. The UEs satisfy 10^-4 PER increased from 80% to 90% (from the dark blue to light blue curve). Can you explain how do you read the other way round?  |
| DOCOMO | Yes |  |
| Intel |  | We don’t have comments given the pre-requisite “If supported”@QC, we don’t deny gains at 1e-4 for Case 2-3 in our curves, but the link adaptation target was set for 1e-5, thus comparing curves at 1e-4 is invalid. We also don’t agree that RU gain for 2nd TX can translate to noticeable gains in satisfied UE ratio, simply due to low probability of 2nd TX. |
| ZTE |  | @moderator: Thanks for the clarification.We share the same view that how to use the UE report is up to gNB implementation and these two ways are both possible. If the gNB use the the case 2 report for scheduling without adjust the backoff, we think the straightforward way is to report the delta MCS/CQI. We are fine with delta MCS, which is the view of the majority companies. If the gNB use the case 2 report for scheduling by adjusting the backoff, it is obvious that the straightforward way is to report the delta SINR. Now the objective is to further study the case 2, which needs to be justified at least by the performance gain. The simulation in our paper shows that the second implementation based on delta SINR has a better performance in terms of the satisfied UE since the backoff is more conservative after the network receives the case 2 report. For further studying the case 2, we suggest companies to evaluate both of the two implementations. Then if case 2 report is supported, the network should have the flexibility to use any of the implementation. Therefore, we suggest adding back delta SINR for the network to adjust the backoff for OLLA. This allows us to evaluate the second implementation. Sorry for not raising this issue earlier. |
| Nokia | Partly  | We shall mention how this delta-MCS is derived. Is it SINR, pre-LLRs, post-LLRs or any other ? Not mentioning this does not help further study as companies already observing different results due to lack of consensus on that. Also, we should mention this is for OLLA initial transmission. We can use this also for re-tranmission if required, but not the main usecase. As the number of bits on delta-MCS is FFS, which means quantity is FFS. Therefore, it is more suitable not to use any terminology like delta-MCS and mention that as “a quantity that indicating SE difference/status for a TB received with a given MCS index indicating a SE value.” Second sub-bullet is not clear to us. What is trying to cover there?  |
| HW/HiSi | No | Agree with the vivo comments on performance comparisom between case 1 and case 2. And we also agree on the issue raised about the computation time. From most companies’ feedback on question 3-5. The CSI report could be sent on the same PUCCH resource as the HARQ-ACK. In that case a computation time reduction is necessary. Without processing time reduction, the A-CSI report under case 2 has to follw the timing of the legacy report. Therefore, to study this case further, we have to compared agree on a reduced processing time and we should also comapored it with case 1.**Regrading the proposal itseld:** We agree on the first sub-bullet (**Report consists of delta-MCS for a TB received with MCS index IMCS:**)The remaining bullets need more discussion:@Paul: Please find our comments to your feedback below:From moderator: *As long as both scheduler and UE know what target BLER the UE assumes, the delta-MCS provides useful information. This does not prevent the scheduler to pick a MCS that would result in a different BLER based on its implementation (as today).* Answer: That is true, but it has significant impact on the number of bits that are required for the delta MCS report as explained in our paper. From moderator: *It may be easier to use (or more accurate) if the BLER that the scheduler wants to achieve is the same as the target BLER the UE assumes for the delta-MCS, but not a hard constraint.* Answer: If gNB and UE have to use the same target BLER, it is either a very hard constraint on the gNB scheduling flexibility (if the gNB has to follow the BLER assumed at the UE), or it is a big problem for the UE implementation complexity and testing (if the UE has to be informed and use the true target BLER for the TB transmissions).Therefore, we think it should be possible that the gNB and UE may use different target BLERS. Based on this assumption, only using the MCS from the scheduled TB as the reference for the delta-MCS report, will lead to either a big quantization error or that many bits need to be spend for the delta-MCS report. That is why we have concerns on the second bullet. At the current stage, we propose to add a FFS to give some more guidance to the choice of BLER values at the gNB and UE side and we also think this discussion has impact on the choice of the reference MCS-value. Is this this slightly updated proposal accteable?**Modified proposal**: **If supported, for the reporting of delta-CQI/MCS**:* **~~Support reporting~~ Report consists of delta-MCS for a TB received with MCS index IMCS:**
* **FFS on BLER target BLER values,**
	+ **If the UE can only assume 1e-5 and or 1e-1, or if it can be any BLER**
	+ **If gNB and UE have to use the same BLER for the MCS calculation**
* **FFS: delta-MCS is largest value such that BLER of the TB received with MCS index IMCS + delta-MCS would be smaller than or equal to a BLER target.**
* **FFS: How ~~to~~ UE determines BLER target,**

**FFS: Number of bits** |
| Sony | Yes |  |
| OPPO | Yes | The modified proposal from Huawei is also acceptable to us.  |
| Ericsson | Yes | Support FL proposal 9.2-1. We can also accept Huawei version. |
| Moderator |  | @Futurewei, vivo: Performance gains are observed by ZTE and Qualcomm for this scheme. InterDigital and Intel results also show gains in certain scenarios/cases.@ZTE: for delta-SINR, prefer not to re-open this discussion. In the simulations anyway, the performance may be more sensitive to the number of bits and how they are mapped to the metric than to the specific choice of the metric. @Nokia: In the evaluations, with the proposed delta-MCS definition of the metric there is no dependency on how it would be derived by the implementation. For OLLA vs retransmission, I think it can be used for either/both. The FFS on number of bits has no bearing on the definition of delta-MCS in my understanding.@HW/HiSi: Since we specify the UE, we should not have an agreement that constrains what the network can do. However, I can add some examples in the FFS for target BLER to reflect these possibilities.@Samsung, CATT, Qualcomm, DOCOMO, Sony, OPPO, Ericsson: Thanks for support. |

**Question 3-5**: Please indicate if FL proposal 9.2-2 is acceptable

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | No | Please see our previous comment on Proposal 9.2-1. |
| Samsung |  | Do not agree with the classification of the “delta\_MCS” as a CSI report in Option 2 – there is no channel state being measured/reported. The “delta\_MCS” can be generally considered as “UE assistance information for MCS selection” – no need to capture anything like that but also no need/justification to have the “as a CSI report” in Option 2 (and in the note). |
| CATT | Yes | We are fine to keep both Option 1 and Option 2 for further discussion. |
| Vivo | No | Whether to support Case 2 reporting should be focused first. |
| QC | YES |  |
| DOCOMO | Yes |  |
| Apple | Yes | We are fine to keep both Option 1 nad Option 2 for further discussion. However the wording “**extended HARQ-ACK codebook” in Option 1** should be changed to **“extended/modified HARQ-ACK codebook”,** as the feedback bits may take different meanings depending whether additional MCS information is associated with them or not, e.g. HARQ feedback over CC1-CC2 are associated with additional delta- MCS, but HARQ feedback over CC3-CC4 is not. |
| ZTE | Yes | We are fine with this proposal. |
| Nokia |  | Similar wording change as in 9.2.-1 may be needed on delta-MCS |
| HW/HiSi | No | We should make the high level decisiosn first. This gies into too much details.Regarding the specific proposal:Option 1 has to be a CSI report. We want to emphasize again that HARQ-ACK enhancements are out of scope. Therefore, if Option 1 is understood as a CSI report that is transmitted on the same PUCCH resource as the HARQ-ACK, it should be fine according to the WID. But if Option 1 implies that the HARQ-ACK itself is extended, e.g. a multi-level ACK/NACK, then this is clearly a HARQ enhancement and out of scope.To clarify this, we want make the following modified proposal:**Modified** **For reporting of delta-MCS (if supported), select between the two following options for the resource:*** **Option 1: delta-MCS is reported jointly on the same PUCCH as the ~~part of an extended~~ HARQ-ACK codebook**
* **Option 2: delta-MCS is reported as a CSI report separate from HARQ-ACK codebook**
	+ **FFS: Type of resource (e.g. PUCCH or higher layers)**

**Note: this does not preclude that the CSI report and HARQ-ACK codebook are multiplexed in same resource per multiplexing rules.** |
| Sony | Yes |  |
| OPPO | Yes |  |
| Ericsson | Yes | We disagree that multi-level ACK/NACK is out of scope. As long as the HARQ-ACK is extended to carry enhanced CSI, it is in scope as CSI enhancement. Nevertheless, we can accept Huawei version if Huawei Option 1 is understood to allow extended HARQ-ACK codebook as well.  |
| Moderator |  | @Samsung, HW/HiSi, Ericsson: OK, I will reformulate to avoid unnecessary discussions on “taxonomy” for the new report.@vivo: will include as FFS in merged proposal@CATT, QC, DOCOMO, Apple, ZTE, Sony, OPPO, Ericsson: Thanks for support. |

# Topic #4: Other enhancements

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

## Summary of issues for Topic #4

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

* Specify CSI enhancements to better fit the needs of SPS PDSCH(s) [6]
* Split CSI report in multiple parts and multiplex as they become available on earliest PUSCH repetition occasion: Lenovo [16]
* Link MCS table to priority indicator: Samsung [16]

One contribution [3] discusses whether to support CSI feedback for PDCCH, and proposes to not support it in R17.

One contribution [5] discusses whether to support priority index 1 for P-CSI/SP-CSI on PUCCH, and proposes to not support it.

One contribution [17] proposes to discuss CSI priority between case 1/case 2/legacy reports.

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

TBD

# References

1. RP-201310 Revised WID: Enhanced IIoT and URLLC support for NR, Nokia, Nokia Shanghai Bell.
2. R1-2104199 CSI feedback enhancements for URLLC FUTUREWEI
3. R1-2104218 CSI Feedback Enhancements for IIoT/URLLC Ericsson
4. R1-2104263 CSI feedback enhancements Huawei, HiSilicon
5. R1-2104327 Discussion on CSI feedback enhancements for eURLLC ZTE
6. R1-2104354 CSI feedback enhancements for Rel-17 URLLC vivo
7. R1-2104421 Discussion on CSI feedback enhancements for Rel-17 URLLC Spreadtrum Communications
8. R1-2104513 CSI feedback enhancements CATT
9. R1-2104605 Discussion on CSI feeback enhancements for URLLC CMCC
10. R1-2104664 CSI enhancement for IOT and URLLC Qualcomm Incorporated
11. R1-2104803 CSI feedback enhancements for URLLC OPPO
12. R1-2104900 Selection of enhanced CSI feedback schemes Intel Corporation
13. R1-2105098 Views on eIIoT/URLLC CSI feedback enhancements Apple
14. R1-2105161 Considerations on CSI feedback enhancements Sony
15. R1-2105186 Discussion on CSI Feedback Enhancements Quectel, Langbo
16. R1-2105303 Improving MCS Selection for URLLC Samsung
17. R1-2105426 Discussion on CSI feedback enhancements for URLLC LG Electronics
18. R1-2105472 CSI feedback enhancements InterDigital, Inc.
19. R1-2105580 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
20. R1-2105694 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
21. R1-2105733 CSI feedback enhancements for URLLC MediaTek Inc.
22. R1-2105767 CSI feedback enhancements for URLLC/IIoT Lenovo, Motorola Mobility
23. R1-2102131, Feature lead summary#4 on CSI feedback enhancements for enhanced URLLC/IIoT, Moderator (InterDigital).
24. R1-2102749 Summary of additional discussions on CSI feedback enhancements for enhanced URLLC/IIoT after RAN1#104-e Moderator (InterDigital, Inc.)
25. R1-2103956, Feature lead summary #4 on CSI feedback enhancements for enhanced URLLC/IIoT, Moderator (InterDigital).
26. R1-2102745 CSI Feedback Enhancements for IIoT/URLLC Ericsson
27. R1-2105958 Selection of enhanced CSI feedback schemes Intel Corporation
28. R1-2106003 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell

# Appendix: Previous agreements

Agreements from RAN1#104b-e

**Conclusion:**

For new reporting Case 1, do not consider further the following schemes:

* Case 1-2: CSI prediction
* Case 1-4: Interference covariance matrix
* Case 1-9: Reference wideband CQI excludes worst sub-bands
* Case 1-10: CSI expiration time

Agreements:

For new reporting Case 2, focus study on reporting of delta-CQI/MCS (Case 2-3):

* Note: this delta-CQI/MCS is determined based on UE implementation (for example, using SINR, LLR, raw BER, flipped bits, LDPC iterations, BLEP, # fail parity checks, etc.)
	+ Companies are encouraged to provide more details in their analysis
* FFS: Granularity of new report type (e.g. units of CQI or MCS, how many bits)
* FFS: Whether quantity reported is relative to the scheduled MCS

Agreement: Focus study on the following for new reporting Case 1:

* Reporting of new metric, where new metric shall be determined based on network configured channel and interference measurement interval (multiple CMR and/or IMR instances) to enable accurate MCS selection.
	+ Downselect by RAN1#105 to at most a single method from the following options:
		- Mean-CQI/SINR and stdev-CQI/SINR (FFS details)
		- CSI based on worst IMR occasion (FFS details)
		- Interference standard deviation (FFS details)
		- Worst-M CQI (FFS details)
	+ FFS: Whether network configured channel and interference measurement interval can also be applied to existing CSI type
* Increasing granularity of subband CQI (e.g. 3-bits differential subband CQI or 4-bits full subband CQI).
* Updating only CQI in a report, where CQI is conditioned on a previous instance in which RI/PMI/(CRI) is updated.
	+ Applicable for same reporting quantity as R16 for CQI.
	+ FFS: Whether network configured channel and interference measurement interval can also be applied
	+ FFS: Whether RI/PMI/(CRI) is transmitted in a report where only CQI is updated
	+ ~~FFS: how to report the updated CQI~~
	+ FFS: whether the CQI processing time can be ~~is~~ reduced compared to Rel-16 CSI processing delay

Final summary in R1-2103956

Agreements from RAN1#104-e

[**R1-2101811**](file:///C%3A/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_104/Docs/R1-2101811.zip)

**Conclusion:** Continue evaluation of new reporting Case 1 and Case 2 for the schemes identified in Appendix B of [R1-2102131](file:///C%3A/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
 |