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

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

**Agenda Item: 8.3.1.2**

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

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

**Document for: Discussion and Decision**

# Introduction

This contribution is a summary of contributions [2]-[24] submitted under AI 8.3.1.2 (CSI feedback enhancements) and few contributions [26]-[27] submitted under AI 8.3.1.1 (HARQ feedback enhancement) which include some proposals related to UE feedback enhancement for more accurate link adaptation. The AI is related to the following objective of the revised work item on Enhanced IIoT and URLLC support for NR [1]:

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| 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 |

# Priority of the issues

**List of the issues identified:**

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

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

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

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

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

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

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

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

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

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

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

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| **Company** | **Priority of the issues** | **Comments** |
| example | High: 1-1, 1-2, 2-1, 3-1  Medium: 1-3, 1-4, 1-5  Low: 1-6, 2-2, 3-2 |  |
| Sony | High: 1-1, 2-1,  Medium: 2-2, 3-1  Low: 1-2, 1-3, 1-4, 1-5, 1-6, 3-2 | Consider feedback for PDCCH. |
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# Enhancements for faster CSI reporting

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

## A-CSI on PUCCH

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

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

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | We do not see the benefit but OK to consider given majority wants it. |
| Samsung | No | Decisions should be based on technical merits, not on a popularity contest.  Next step can be to identify technical merits under realistic assumptions and discuss/conclude on those assumptions. |
| Nokia/NSB | No | To our understanding, the Rel-17 discussion should be for CSI feedback enhancements to allow for more accurate MCS selection. This A-CSI on PUCCH was discussed during Rel-16 SI phase, but there was no sufficient gain to be included in the Rel-16 URLLC WI. Need better justification unless performance gains are showed compared to other proposals in this agenda item.  Also, we see that there are many other related problems arise with this solution vs compared to other solutions, and we have a limited time in the WI to finalize may be only one main direction due to that.  May be a good approach for now is that keep this just as one possible solution for further studies. |

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

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | No | It isn’t useful for 1st PDSCH transmission. If we really want it for the retransmission (which is supposed to be rare in URLLC), then can consider Option 3. |
| Samsung | No | Majority support should not be the reason for an agreement. |
| Nokia/NSB | No | The question 2 heavily dependent on answer to question 1. Agree also with Samsung. |

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

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

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

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

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

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

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

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony |  | Consider the details after agreeing whether to support or not support this feature. |
| Samsung | Yes | For the reasons mentioned in “Question #3” |
| Nokia/NSB |  | These issues can be revisited once the basic direction of the solution is identified. |
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## Reduction of CSI computation time

**Background**

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

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

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

**Observations**

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | No | This issue is created due to DL Grant triggered A-CSI, which we do not think is beneficial for URLLC purpose. |
| Samsung | No | This is difficult for UE implementation – no meaningful reductions are possible. |
| Nokia/NSB | No | First, we should investigate the performance impact or gains compared to the increase in complexity at the UE side. In our investigations, considering the case of increasing the CQI reporting frequency or reducing the ‘CQI processing delay’ does not make a huge difference to URLLC performance, since the channel (especially intereference) coherence time is extremely small. |

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Agree to consider this after decision is made for A-CSI on PUCCH. |
| Samsung | No | There is only a lower level relevance. |
| Nokia | No | We assume that the FL refer to the A-CSI computation time. We would be happy if the UE can reduce the computation times, but it looks to us that this kind of seperate investigations are not within WI objective. |

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

**Background**

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

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

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

**Observations**

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | No | CSI is not so critical for latency purpose as the gNB can still schedule the UE without the latest CSI report. However, if we attach a high priority to CSI and it collides with a LP PUSCH, the LP PUSCH is dropped, which is an overkill. Whereas in Rel-16, the CSI can be muxltiplexed into the LP PUSCH thereby transmitting both to the gNB, which is a better outcome. |
| Samsung | Yes | Because separate report is needed for URLLC (e.g. low MCS table) and can be often dropped either due to collisions or due to resource availability when multiplexed with HARQ-ACK. Spec impact is practically zero. |
| Nokia/NSB | No | We do not see the necessity of having high priority index 1 for P/SP-CSI even for URLLC traffic as already agreed in Rel-16. |

# Enhancements for more accurate CSI reporting

## Enhancements for bursty interference conditions

**Background**

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

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

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

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

**Observation**

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | More information especially on the characteristic of the intereference is useful for accurate MCS selection at the gNB. |
| Samsung | No | Robustness is key in URLLC. Short-term/instantaneous statistics cannot be relied upon for future scheduling. There is also always the issue with accuracy of measurements, quantizations, and reliable, practically error-free, feedback, dependence on transmission scheme, diversity scheme, .... |
| Nokia/NSB | Yes | As we see from our evalutions, we see certain gains with such approaches. It is convenient to have an agreed/unified way forward for comparing the performance of the different proposals. |

## More accurate sub-band CQI feedback

**Background**

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

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

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Can be further studied but not high priority. |
| Samsung | Maybe | Rel-15 provides the necessary tools for sub-band CSI reporting. New simpler reporting modes can be considered. But overlap with similar work in Rel-17 MIMO should be avoided. |
| Nokia/NSB | No | We prefer to have alternative CSI/CQI report types (e.g. as in Section 4.1) which can provide similar benefits with (much) lower uplink reporting overhead.  As a potential way forward, the decision between new CSI/CQI report types and/or enhanced sub-band reporting can be based on performance evaluation. |

# Other enhancements

## Enhancements to support OLLA with low BLER target

**Background**

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

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

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

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

**Observation**

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | We can consider the details after decision is made on this feature. |
| Samsung | Maybe | Need to have evaluation first and identify potential benefits – cannot say ‘yes’ or ‘no’ to concepts. Several proposals fall under MIMO (and some are part of Rel-17 MIMO). The remaining do not seem necessary. |
| Nokia, NSB | Yes | For outer loop link adaptation, we see it convenient to derive the additional information from the PDSCH. |

## Enhancements for URLLC in multi-TRP scenarios

**Background**

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

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

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

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | No | Leave it to MIMO group to handle. |
| Samsung | No | Rel-17 MIMO is handling this. |
| Nokia, NSB | No | Let MIMO guys to handle this. |

## Miscellaneous Enhancements

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

Lenovo [13] proposal

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

CMCC [17] proposal

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

Qualcomm [24] proposals

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

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

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| **Company** | **Yes/No** | **Comments** |
| Sony | Yes | Can consider feedbacks for PDCCH. |
| Samsung | Yes | PDCCH link adaptation is more important than PDSCH one, especially for the small TBs and low latency of URLLC – cannot even receive the PDSCH without the PDCCH and the latter cannot even benefit from HARQ |
| Nokia | No |  |

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

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| **Company** | **Comments** |
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# References

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2. R1-2005244 CSI feedback enhancements Huawei, HiSilicon
3. R1-2005281 CSI feedback enhancements for URLLC FUTUREWEI
4. R1-2005375 CSI feedback enhancements for Rel-17 URLLC vivo
5. R1-2005432 Discussion on CSI feedback enhancements for eURLLC ZTE
6. R1-2005514 CSI Feedback Enhancements for IIoT/URLLC Ericsson
7. R1-2005552 CSI feedback enhancements for URLLC/IIoT use cases Nokia, Nokia Shanghai Bell
8. R1-2005570 Considerations on CSI feedback enhancements Sony
9. R1-2005634 CSI feedback enhancements for URLLC MediaTek Inc.
10. R1-2005702 CSI feedback enhancements CATT
11. R1-2005776 CSI feedback enhancement NEC
12. R1-2005870 CSI feedback enhancements in Release 17 URLLC/IIoT Intel Corporation
13. R1-2005930 CSI feedback enhancements Lenovo, Motorola Mobility
14. R1-2006059 Enhancement for CSI feedback OPPO
15. R1-2006071 CSI feedback enhancements for enhanced URLLC/IIoT InterDigital, Inc.
16. R1-2006140 CSI feedback enhancements for URLLC Samsung
17. R1-2006208 Discussion on CSI feedback enhancements CMCC
18. R1-2006276 Discussion on CSI feedback enhancements Spreadtrum Communications
19. R1-2006315 Discussion on CSI feedback enhancements for URLLC LG Electronics
20. R1-2006343 Discussion on CSI feedback enhancements Panasonic Corporation
21. R1-2006515 CSI feedback enhancements for URLLC Apple
22. R1-2006573 CSI feedback enhancements for eURLLC Sharp, NICT
23. R1-2006729 Discussion on CSI feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
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