**3GPP TSG RAN WG1 #108-e** **R1-22xxxxx**

e-Meeting, February 21st – March 3rd, 2022

**Agenda item:** 7.1

**Source:** Moderator (Samsung)

**Title:** Summary of [108-e-NR-CRs-12]: UCI multiplexing in PUSCH with repetitions

**Document for:** Discussion and Decision

# Introduction

This document provides the inputs to the email discussions for [108-e-NR-CRs-13] regarding the draft CR in R1-2201989.

[108-e-NR-CRs-12] Issue#13 UCI multiplexing in PUSCH with repetitions – Aris (Samsung)

* Relevant tdocs: R1-2201988, R1-2201989
* Check point on February 23

# Background

In RAN1#91, the following was agreed.

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| **Agreement: (RAN1#91)*** For UCI on PUSCH with UL-SCH, the amount of resources used for HARQ-ACK is calculated based on the following equation.

$Q^{'}=\left⌈\frac{O⋅M\_{sc}^{PUSCH}⋅N\_{symb}^{PUSCH}⋅β\_{offset}^{HARQ-ACK}}{\sum\_{r=0}^{C-1}K\_{r}}\right⌉$ where $O$ is the number of ACK/NACK bits, $M\_{sc}^{PUSCH}$ is the scheduled bandwidth for PUSCH transmission in the current PUSCH transmission period for the transport block, expressed as a number of subcarriers. $C$, and $K\_{r}$ are obtained from the PDCCH scheduling the PUSCH transmission. $N\_{symb}^{PUSCH}$ **is the number of OFDM symbols in the PUSCH transmission duration** excluding DMRS. REs occupied by PTRS are also excluded.  |

# Problem description

TS 38.212 does not implement $N\_{symb}^{PUSCH}$ as “the number of symbols in the PUSCH transmission duration” as in the RAN1 agreement above – in 38.212, $N\_{symb}^{PUSCH}$ is the number of symbols for PUSCH in one slot (excluding DMRS).

As a result, 38.212 correctly implements the RAN1#91 agreement only for single slot PUSCH transmission and for Rel-17 TBoMS (due to the scaling by the number of slots) - it does not for Type-A/B repetitions.

The incorrect implementation in 38.212 of the RAN1#91 agreement in case of PUSCH repetitions (Type-A or nominal Type-B) leads to nonsensical outcomes.

For example, consider a given {symbol/RB allocation in a slot for a PUSCH, TB BLER, UCI payload, UCI BLER}.

If the PUSCH is with 10 repetitions, the SINR per RE is ~10 dB less than if the PUSCH is without repetitions. Yet, according to 38.212, the number of REs for UCI is same (despite the fact that the SINR per RE is ~10 dB less in case of repetitions than in case of no repetitions).

Similar, if the PUSCH is over 10 slots with TBoMS, the number of REs for UCI (according to 38.212) is 10 times larger than if the PUSCH is over 10 slots with repetitions (despite the fact that the SINR per RE is practically same).

Another issue is whether or not “the specs are broken”.

For “small” number of repetitions (e.g. < 8) and “small” ratios of TB BLER to UCI BLER (e.g. <=10), one of the largest values of beta\_offset can work. The specs are not broken although there will be latency/SE loss (particularly for URLLC) for DCI-based number of repetitions and RRC-based beta\_offset because the gNB needs to provision for “worst-case” to ensure UCI reliability.

For “large” number of repetitions (e.g. >= 8), or “large” ratios of TB BLER to UCI BLER (e.g. >20, not unusual in case of repetitions to target ~30% TB BLER), UCI reliability is lost. Even the largest beta\_offset value is not enough. In that sense, the specs are broken.

# 1st round discussions

Q1: Do you agree with the statement that “TS 38.212 does not implement the RAN1#91 agreement for determining the number of UCI REs for multiplexing UCI in a PUSCH transmission with repetitions”? Please justify your input.

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| --- | --- | --- |
| Company | Yes/No | Comment/Reason |
| QC |  | The scope of the discussion when people agreed on the RAN1#91 agreement was on PUSCH without repetition. I don’t recall PUSCH with repetitions was included in the discussion. I admit it was an oversight, but the intention of that agreement was for PUSCH without repetition, if I recall correctly.  |
| NTT DOCOMO | No | We have same view with QC. Whether the agreement considers repetition as well or not is unclear, so probably it is difficult to say “212 does not implement the RAN1#91 agreement”. |
| Huawei, HiSilicon | No | In our understanding, the UCI bits are multiplexed only on one PUSCH transmission. Even for PUSCH with repetition, they are multiplexed only on the one repetition overlapping with PUCCH. So we think current 212 spec reflects the agreement correctly. |
| LG | No | We have similar view with Huawei. Since the UCI bits in an overlapping PUCCH are multiplexed only on one PUSCH (not over multiple PUSCHs) of PUSCH repetitions, current 212 spec seems to well reflect the agreement. |
| Nokia, NSB | No | We have a similar view as Huawei and LG. |
| vivo | No | We have a similar view as Huawei and LG. |
| ZTE | No | Share the same view with Huawei and LG. |
| Intel | No | We share similar view as Huawei. |
| Samsung | Yes | For PUSCH repetitions, UCI bits are not multiplexed in one PUSCH transmission – they are multiplexed in one repetition of a PUSCH transmission. Also, although the discussions in RAN1#91 may or may not had explicitly considered repetitions, they certainly considered that the scaling adjusts according to the PUSCH spectral efficiency which is the same thing (and is directly captured for the CSI-only case). The inconsistency between the agreement “*the number of symbols in the PUSCH transmission duration*” and the specifications “*the number of symbols for PUSCH in one slot*” couldn’t be clearer.  |
| Apple | No | We are not sure if PUSCH repetitions were considered at the point when the agreement was made, so we would not say the spec does not capture the agreement correctly. On the other hand, of course it could be arguable whether the current spec has the best solution for the case with repetitions or not. But this is a different story. |

Q2: Do you agree with the statement that “TS 38.212 results to an inadequate number of REs for UCI multiplexing for a PUSCH transmission with repetitions – that number is inconsistent with the number for the case of no repetitions or, in Rel-17, for the case of TBoMS”? Please justify your input.

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| Company | Yes/No | Comment/Reason |
| QC |  | We acknowledge the issue identified in the CR. But there are other ways to bypass the issue such as configuring/signalling larger beta-offset values. |
| NTT DOCOMO | No | As commented, large beta-offset can be configured/indicated for adequate number of REs for UCI mux.  |
| Huawei, HiSilicon | No | As replied in Q1, the multiplexing procedure is the same for PUSCH with or without repetition. |
| LG | No | Similar view with Huawei. |
| Nokia, NSB | No | Similar view as Huawei and LG. |
| vivo | No | Similar view as Huawei. |
| ZTE | No | Share the same view with Huawei and LG. |
| Intel | No | Larger beta offset values can be configured/indicated to increase the number of REs for UCI on PUSCH repetition.  |
| Samsung | Yes | Larger beta\_offset values do not work in general. For a relatively large number of repetitions, or for a relatively large ratio of TB BLER over UCI BLER and repetitions, even the largest allowed beta\_offset is not large enough. As a side note, it is not understood how companies can suggest to use larger beta\_offset values to solve the issue and also suggest ‘No’ to Q1. That the multiplexing procedure is same with/without repetitions is irrelevant – the question is about the number of REs required for each case. It should also be clear that the current formulas produce nonsensical results when compared to the results for the cases of no repetitions or TBoMS which implement the RAN1#91 agreement. |
| Apple |  | As we said it is arguable whether the solution in the spec is the best one or not. But as mentioned by other companies, we do have the work-around to use larger beta\_offset to make it work. Given that it has been in the spec since R15/R16 for a long time, we do not think we should change it at this stage. |

Q3: If the answer is ‘yes’ to Q1, do you agree that the specifications in 38.212 for determining the number of UCI REs for multiplexing UCI in a PUSCH transmission with repetitions need to be corrected (starting from Rel-16)? Please justify your input.

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| Company | Yes/No | Comment/Reasons |
| QC | No | Like we commented for previous question, there are other ways to bypass the issue such as configuring/signalling larger beta-offset values.Furthermore, the proposal of scaling up # REs based on repetition factor N opens up a few new issues such as 1) what if some of the PUSCH repetitions get dropped; 2) PUSCH Type B repetitions may have different actual PUSCH coding rate cross repetitions already; 3) How to deal with Rel-17 A-CSI repetitions (introduced in M-TRP) on PUSCH. Last but not least, Rel 15/16 UE already implement based on current spec.With the above, we don’t agree to change current spec for this issue.  |
| Huawei, HiSilicon | No | We have not seen any issues in current spec on multiplexing UCI on PUSCH with repetition. On other hand, we share views with QC, Rel-15/16 UE has already implemented based on current spec, and such changes may be not backward compatible for them. So we do not agree to change current spec. |
| LG | No | We have similar view with above companies. As replied in Q1 and Q2, the correction doesn’t seem to be necessary. |
| vivo | No | Similar view as Huawei. |
| Samsung | Yes | Specifications should be according to agreements and, for the present case, should enable UCI reliability in all supported scenarios. Neither of these is currently true. Also, 3GPP should be mindful for the quality of the specifications it produces as viewed by the industry at large. The change is proposed for Rel-16, not for Rel-15, and is a trivial software one. |

# 2nd round discussions

# Summary and conclusions