**3GPP TSG RAN WG1 #104-e R1-210XXXX**

**e-Meeting, January 25th – February 5th, 2021**

**Agenda item:** 7.1

**Source:** Moderator (CATT)

**Title:** Summary of [104-e-NR-7.1CRs-15] Draft CR on Type-2 HARQ -ACK codebook in physical uplink shared channel

**Document for:** Discussion and Decision

# Introduction

This document is created to facilitate the email discussion of “[104-e-NR-7.1CRs-15] Draft CR on Type-2 HARQ-ACK codebook in physical uplink shared channel”. This email thread is triggered by draft CRs in [1][2][3].

According to TS38.213 clause 9.1.3.2, for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by a DCI format 0\_1, UE generates the HARQ-ACK codebook as described in Clause 9.1.3.1 according to the value of  in the DCI format 0\_1, which is used to indicate the total number of HARQ-ACKs in response to PDSCHs associated with PDCCH and PDCCH indicating SPS PDSCH release to be multiplexed in the PUSCH.

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| If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by DCI format 0\_1, the UE generates the HARQ-ACK codebook as described in Clause 9.1.3.1, with the following modifications:- For the pseudo-code for the HARQ-ACK codebook generation in Clause 9.1.3.1, after the completion of the  and  loops, the UE sets  where  is the value of the DAI field in DCI format 0\_1 according to Table 9.1.3-2- For the case of first and second HARQ-ACK sub-codebooks, DCI format 0\_1 includes a first DAI field corresponding to the first HARQ-ACK sub-codebook and a second DAI field corresponding to the second HARQ-ACK sub-codebook*- harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*. |

The HARQ-ACK for SPS PDSCH, if any, is appended after the HARQ-ACK(s) in response to PDSCHs associated with PDCCH and PDCCH indicating SPS PDSCH release.

In addition, it is specified in TS38.213 clause 9.1.3.2 that for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by DCI format 0\_1, if  in the DCI format 0\_1 and UE has no HARQ-ACK(s) in response to PDSCHs associated with PDCCH, PDCCH indicating SPS PDSCH release or SPS PDSCH, the UE does not multiplex HARQ-ACK in the PUSCH.

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| If a UE is not provided *PDSCH-CodeBlockGroupTransmission* and the UE is scheduled for a PUSCH transmission by DCI format 0\_1 with DAI field value  and the UE has not received any PDCCH within the monitoring occasions for PDCCH with DCI format 1\_0 or DCI format 1\_1 for scheduling PDSCH receptions or SPS PDSCH release on any serving cell  and the UE does not have HARQ-ACK information in response to a SPS PDSCH reception to multiplex in the PUSCH, as described in Clause 9.1.3.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission. If a UE is provided *PDSCH-CodeBlockGroupTransmission* and the UE is scheduled for a PUSCH transmission by DCI format 0\_1 with first DAI field value  or with second DAI field value  and the UE has not received any PDCCH within the monitoring occasions for PDCCH with DCI format 1\_0 or with DCI format 1\_1, respectively, for scheduling PDSCH receptions or SPS PDSCH release on any serving cell  and the UE does not have HARQ-ACK information in response to a SPS PDSCH reception to multiplex in the PUSCH, as described in Clause 9.1.3.1, the UE does not multiplex HARQ-ACK information for the first sub-codebook or for the second sub-codebook, respectively, in the PUSCH transmission. |

However, for the similar case as above except that UE has HARQ-ACK for SPS PDSCH to be multiplexed in the PUSCH, UE would multiplex 5 bits in the PUSCH according to Rel-15 specifications. Therefore, the draft CRs in [1][2][3] propose to clarify that for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by DCI format 0\_1, if  in the DCI format 0\_1 and UE has HARQ-ACK(s) for SPS PDSCH only (i.e. no HARQ-ACK(s) in response to PDSCHs associated with PDCCH or PDCCH(s) indicating SPS PDSCH release), the UE multiplexes HARQ-ACK(s) for SPS PDSCH only in the PUSCH.

# Company views

**Q1:** In Rel-15, for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by DCI format 0\_1, if  in the DCI format 0\_1 and UE has a HARQ-ACK for SPS PDSCH only (i.e. no HARQ-ACK(s) in response to PDSCHs associated with PDCCH or PDCCH(s) indicating SPS PDSCH release), **what is the intended UE behaviour**?

* Alternative 1: UE multiplexes 1-bit HARQ-ACK for SPS PDSCH in the PUSCH
* Alternative 2: UE multiplexes 5-bit HARQ-ACKs in the PUSCH

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| **Company** | **Alternative 1 or Alternative 2** | **Comment** |
| OPPO | Alternative 2, if  in the DCI format 0\_1 | If only one SPS PDSCH is transmitted by gNB, the value of  in the DCI format 0\_1 should be smaller, e.g. 1. If the value of  in the DCI format 0\_1 is 4, then the intended behavior is alternative 2. |
| vivo | Alternative 1 | DAI in the DCI format 0\_1 is used to count DG PDSCHs/SPS release only without considering SPS PDSCH.  is used to indicate there is no HARQ-ACK for DG PDSCH/SPS release (if the UE has not received any PDCCH within the monitoring occasions). |
| Qualcomm |  | We expect to see different answers to this question. But this is not the main point. The point is that: is this a critical issue to begin with? Our view is that this is just a corner case, not a critical issue. gNB can set =1 to bypass the issue. At this stage, we don’t want to introduce NBC change to Rel-15 spec, unless it is definitely needed. Unfortunately, this issue does not meet the bar for Rel-15 NBC change.  |
| NTT DOCOMO | Alt 1 | In this situation, only 1 bit HARQ-ACK should be the intended behavior. |
| Huawei | Alt.1 | When the issue was discussed, the intended UE behavior was that only 1 bit HARQ-ACK is multiplexed on PUSCH. However, the current specification still works and system is not broken. |
| ZTE | Alternative 1 | The interpretation follows the similar behavior of LTE as  is used to indicate there is no HARQ-ACK for DG PDSCH/SPS release.For the type-2 codebook, there is a basic assumption that the UE will not continuously miss 4 PDCCHs, which is the basic assumption for DL DAI counting. In order to reduce unnecessary overhead, when the base station does not schedule any DG PDSCH or release DCI for the UE, the base station informs the UE about this situation by setting UL DAI=4, which is also using the aforementioned basic assumptions. Correspondingly, the UE does not detect any PDCCH for DG PDSCH or release SPS, and UL DAI=4 is set in the UL grant. In this case, the UE will assume that the base station does not schedule any DG PDSCH or release DCI, so the UE does not generate HARQ-ACK. However, if Alt2 is intended to be the behaviour, the UE will assume 4 PDCCHs are continuously missed, and the UE generates 4 NACKs. Obviously, for Alt1, the basic assumption of type2 codebook can be maintained, but for Alt2, the basic assumption of type2 codebook will be broken. |
| Samsung |  | We don’t understand question well. Why intended behavior is considered here without considering current specification? It should not mix up with V\_T-DAI=4.  |
| MediaTek | Alternative 2 | We cannot understand the intention of the question too. The described scenario is a corner case and it looks that the current specification works well. In our understanding, Alt 1 is an optimization and introduces NBC change. |
| Intel |  | We think the default understanding should be Alternative 1, since there is no dynamic PDSCH/SPS release and only 1 bit for SPS PDSCH. However, at this quite late stage, we prefer to exactly follow the specification since it anyway works |
| LG |  | Even though the motivation of this CR is understood, it seems to be an optimization associated with NBC issue at this stage.Moreover, as companies already mentioned, current spec anyhow works even without this CR.If 5-bit HARQ-ACK is considered as some overhead from gNB perspective, then the gNB could indicate UL DAI = 1 rather than 4 in such case so that the UE would report 2-bit HARQ-ACK as {NACK, SPS HARQ-ACK}. |
| Apple |  | Alternative 1 follows LTE behavior and for consistency, the solution should be similar. However, as has been mentioned, Alternative 2 works today and the gNB can modify its signaling to drop the additional overhead from 4 to 1. As such, we don’t think the change is critical. |
| Ericsson |  | From our point of view as NW vendor, it is important that UEs behave similarly. We do agree the case could be a corner case, but we are more concern on the outcome with respect to next question (Q2). |
| Nokia |  | Alt 1 would be the logical way for the spec to operate, but the question is irrelevant at this stage. What matters is how we interpret the spec. |

**Q2:** In Rel-15, for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by DCI format 0\_1, if  in the DCI format 0\_1 and UE has a HARQ-ACK for SPS PDSCH only (i.e. no HARQ-ACK(s) in response to PDSCHs associated with PDCCH or PDCCH(s) indicating SPS PDSCH release), **what is the UE behaviour according to current specification**?

* Alternative 1: UE multiplexes 1-bit HARQ-ACK for SPS PDSCH in the PUSCH
* Alternative 2: UE multiplexes 5-bit HARQ-ACKs in the PUSCH

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| **Company** | **Alternative 1 or Alternative 2** | **Comment** |
| OPPO | Alternative 2 | The same comment as Q1 |
| vivo | Alternative ~~1~~ 2 | The same comment as Q1 |
| Qualcomm |  | Same comment as to Q1 |
| NTT DOCOMO | Alt 2 | Based on the current pseudo-code, if V^UL\_DAI is 4, it seems that unnecessary 4-bits are generated before generating HARQ-ACK for SPS PDSCH. |
| Huawei | Alt.2 | The HARQ-ACK bits is generated based on the pseudo-code. In this case, the UE will multiplex 5 bits in PUSCH. |
| ZTE | Alternative 2 | For type 2 HARQ-ACK codebook, 4 dummy bits for DG PDSCH/SPS release are generated. |
| Samsung | Alt. 2 |  |
| MediaTek | Alt 2 | Same comment as Q1 |
| Intel | Alt 2 |  |
| LG | Alt 2 |  |
| Apple | Alt 2 |  |
| Ericsson |  | Same comment as Q1.It seems all companies who showed preference agree with Alt 2, except vivo. As mentioned in Q1, it is important for us to conclude on one option (seems to be Alt 2). See more in next question. |
| Nokia | Alt 2 | The CR seems to be an attempt to optimize the currently suboptimal HARQ-ACK feedback for this particular setup. |

**Q3:** Do you agree with the principle of the CRs? If not, why?

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| **Company** | **Agree or not** | **Comment** |
| OPPO | No | Current specification works. It is not an essential issue. |
| Vivo | agree |  |
| Qualcomm | No | Similar to OPPO’s view, this is not a critical issue. Current specification works. No need to introduce NBC change to Rel-15 spec to address this noncritical issue.  |
| NTT DOCOMO | No for at least Rel-15 | This CR for Rel-15 would be NBC change.For Rel-16, the change might be OK. |
| Huawei | No | It is NBC change for Rel-15 and the issue is not critical. |
| ZTE | Yes | The basic assumption that the UE will not continuously miss 4 PDCCHs for DL DAI counting should be assumed as before. It should be clarified the number of HARQ-ACK bits for multiplexing on PUSCH in case a UE has no PDSCH reception scheduled by a DCI format or SPS PDSCH release while has SPS PDSCH reception. Otherwise this would cause unexpected HARQ-ACK bits to be generated.If companies think it is an NBC change for Rel-15 CR, at least we need to reach a common understanding/conclusion for Rel-15, and we can remedy it for Rel-16. |
| Samsung | No  | At lease, we have strong concern on Rel-15 CR since Rel-15 CR has very high bar and other operation can provide similar behaviour such that DCI format 1\_0 or DCI format 1\_1 with T\_DAI=1 for less overhead.  |
| MediaTek | No | The issues is not critical and introduces NBC change. |
| Intel | No | Reporting 5 bits is not our favourite, however it can be acceptable in the late stage. |
| LG | No | Already answered in Q1. |
| Apple | No | The existing solution, although inefficient, works. |
| Ericsson |  | Emphasising that a common understanding is critical for us, we are fine to have a conclusion to confirm that.  |
| Nokia | Not according to the current proposal as it would be a change of Rel-15 behaviour | Concluding that Alt.2 is the intended behaviour, or even clarifying that with a CR would be acceptable to us. |

# Intermediate proposals

Based on the inputs in section 2, the Rel-15 CR seems not agreeable due to NBC issue but still the discussion is helpful to align the understandings on the UE behavior according to the current specifications. Therefore, a proposed conclusion is proposed below to clarify the UE behavior in Rel-15.

Possible conclusion:

In Rel-15, for a type-2 HARQ-ACK codebook transmission in a PUSCH scheduled by DCI format 0\_1 with $V\_{T-DAI}^{UL}=A$ and UE has a HARQ-ACK for SPS PDSCH only (i.e. no HARQ-ACK(s) in response to PDSCHs associated with PDCCH or PDCCH(s) indicating SPS PDSCH release) to be transmitted in the PUSCH, UE multiplexes A+1 bits HARQ-ACK in the PUSCH.

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| **Company** | **Do you agree with the proposed conclusion?** | **Comment** |
| QC | No | Like we commented in first round, this is a corner case. No need to take action for this corner case.  |
| vivo | No | Sorry for the copy and paste error for above Q2. Based on the current specification, it should be alt 2. we think our understandings are aligned and no conclusion is needed. |
| Samsung | Conditionally Yes | If all companies have same understanding based on possible conclusion, this is not needed. Otherwise, we think that this is beneficial to have common understanding.  |
| ZTE | Yes |  |
| OPPO | No | Our understandings are aligned and no conclusion is needed. |
| LG | No | We share the same view with other companies that it seems no conclusion is needed. |
| Huawei | No | Given that companies have common understanding for the above case, we don’t see the need of the conclusion for Rel-15 |

For Rel-16, considering that SPS enhancements including shorter SPS periodicity and multiple SPS configurations are introduced in eURLLC, there could be much more HARQ-ACK feedbacks for SPS PDSCH in different slots/sub-slots so that the probability of redundant HARQ-ACK feedback in PUSCH could be much higher than in Rel-15. To that end and also considering it is for Rel-16, moderator would like to see whether a Rel-16 CR as in R1-2100325 is acceptable to the group.

Proposal: Adopt Rel-16 CR as in R1-2100325.

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| **Company** | **Do you agree with the proposal?** | **Comment** |
| vivo | Agree in principle | If companies think it is an NBC change for Rel-15 CR, at least for Rel-16, we can accept the CR. |
| Samsung | Agree |  |
| ZTE | Agree | For Rel-16, considering that SPS enhancements with shorter SPS periodicity and multiple SPS configurations are introduced in eURLLC. If a shorter period of SPS is configured, A+1 bit feedback will occur frequently. We believe that dummy A bits should be avoided through specification effort in Rel-16.Then we support the CR in R1-2100325.  |
| MediaTek | No | As commented by some companies in the first round discussion, the overhead for dummy bits can be reduced by proper network indication. So, it is not clear to us whether the issue is really essential…  |
| OPPO | No | Firstly, condition for issue are :1) only SPS PDSCH transmission 2) Type 2 HARQ-ACK codebook is applied 3) UCI is multiplexed in PUSCH. Although shorter SPS periodicity and multiple SPS configurations are introduced in eURLLC, it does not mean that issue occurs frequently due to all of three conditions need to be satisfied.As commented before, it is not an essential issue but enhancement. Enhancement should be avoided at CR stage. If support, new UE capability is required. And which feature group does the enhancement belong to? Feature group related with URLLC ?  |
| LG | No | Agree with other companies that it doesn’t seem to be essential issue since it could be handled by gNB’s proper indication.  |
| Huawei | No | If we adopt a different approach for Rel-16, we will need to define a new UE capability dedicated for this as well as a configuration to enable the new UE behavior. Otherwise, there may be misunderstanding between the UE and gNB. From UE point of view, it anyway needs to support the two UE behaviors.  |

# Conclusion

To be added after the discussion.

# Reference

1. [R1-2100083](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100083.zip) Draft CR on Type-2 HARQ-ACK codebook in physical uplink shared channel ZTE

1. [R1-2100324](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100324.zip) Correction on HARQ-ACK transmission in PUSCH CATT

1. [R1-2100325](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100325.zip) Correction on HARQ-ACK transmission in PUSCH CATT