**3GPP TSG-RAN WG1 Meeting #117 R1-240XXXX**

**Fukuoka, Japan, May 20th-24th, 2024**

**Agenda Item: 8.1**

**Source: Moderator (Huawei)**

**Title: Summary of discussion on** **HARQ-ACK multiplexing on a PUSCH repetition**

**Document for: Discussion and Decision**

# Introduction

In past few meetings, companies would like to clarify the wording on Rel-18 TEI HARQ-ACK multiplexing on a PUSCH repetition to cover a missing case, however, no final CR is agreed. This document is created to further discuss related issues and collect company views on the corrections in [1][2][3].

# Problem description

In RAN1#115, the following agreement was updated for Rel-18 TEI regarding removing the restriction on scheduling PDSCH after UL grant for the case of PUSCH with repetitions.

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| **Agreement (RAN1#115)**  **Update the previous agreement made RAN1#113 as following,**  Agreement  If UCI multiplexing of different priorities is not enabled, the restriction on scheduling PDSCH after UL grant is removed for the case of PUSCH with repetitions except the first repetition   * UE generates Type-1 HARQ-ACK codebook according to the existing specification with the modification of setting the actual ‘ACK/NACK’ value corresponding to PDSCH(s) scheduled after the UL grant. * UE generates Type-2/3 HARQ-ACK codebook according to the existing specification.   + For Type-2 CB, UL DAI is used for generating HARQ CB. * This feature is subject to separate UE capabilities for type-1, type-2, and type-3 codebooks. * RRC parameter(s) to configure the function of scheduling PDSCH after a UL DCI format and multiplexing associated HARQ on a PUSCH repetition except the first repetition are introduced in Rel-18. * Note: the number of PUSCH repetitions can be scheduled/configured by gNB. * Note: same principle of current specification which UL DAI in UL grant is applied to each PUSCH repetition is reused. * The timeline specified in TS 38.213 Clause 9.2.3 and 9.2.5 are satisfied, i.e. between the last PDSCH and PUCCH, between the last PDCCH among UL grant /DL grant(s) and the earliest PUCCH or PUSCH. * Additional UE capabilities are introduced to support the following functions (UE will be configured by gNB to use the following features via RRC)   + HARQ-ACK codebook size change on a PUCCH slot   + PUCCH time domain resource change on a PUCCH slot * The above feature cannot be simultaneously enabled with PUCCH carrier switching. |

However, in [1][2][3], company explain the reference to determine “same time domain” or “same codebook size” is not clear in the spec, if either “*enableDiffPUCCH-Resource*” or “*enableDiffCB-Size*” is not provided to UE, and illustrate in further, RAN1 has already clarified the supported cases for Rel-18 TEI in RAN1 #116 in following conclusion, but the case 2 in R1-2400675 is not captured exactly in the spec.

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| **Conclusion**   * The Case 1 and Case 2 in [R1-2400675](file:///C:\3gpp\Meetings\TSGR1\TSGR1_116\Docs\R1-2400675.zip) are supported by existing TEI agreements made in RAN1#115.   Case 2 in [R1-2400675](file:///C:\3gpp\Meetings\TSGR1\TSGR1_116\Docs\R1-2400675.zip) is supported with UE capability FG 55-4e. |

Therefore, corrections are provided in [1][2][3].

On other hand, in [2], it also corrects the RRC signaling which agreed in RAN #103.

# 1st round Discussion

## Companies’ view

From moderator’s view, the issue has been discussed for serval meetings, and it is not needed to re-discuss the necessity to have a spec change or conclusion, if any. Therefore, moderator’s suggestion is going to discuss the CR provided in [1][2][3] directly.

**CR#1 in [1]**

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| 9 UE procedure for reporting control information **<Unchanged parts are omitted>**  A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE  - detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is not provided any of *enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant*, or  - is provided *uci-MuxWithDiffPrio*, or  - transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,  the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE  - previously detects a second DCI format scheduling the PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is provided *enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant*, and  - is not provided *uci-MuxWithDiffPrio*, and  - transmits a repetition of a PUSCH transmission other than a first repetition,  the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format indicating a first resource for a first PUCCH transmission in a slot, when  - the UE detects a second DCI format, in a PDCCH monitoring occasion that starts before the PDCCH monitoring occasion for the first DCI format, scheduling a PUSCH transmission in the slot, and  - the first resource overlaps with one repetition of the PUSCH transmission, and  - the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and  - the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of and for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied, and  - the first PUCCH resource is the same in the time domain as a second PUCCH resource that UE does not determine for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource*, and  - the second PUCCH resource is indicated by the last DL DCI format in a PDCCH monitoring occasion that starts before the PDCCH monitoring occasion for the second DCI format, or  - the second PUCCH resource is for the PUCCH transmission with the HARQ-ACK information associated only with SPS PDSCHs, and  - the UE determines that the HARQ-ACK codebook has the same size with or without the HARQ-ACK information associated with the PDSCH reception scheduled by the first DCI format if the UE is not provided *enable-different-CBsize*.  **<Unchanged parts are omitted>** |

**CR#2 in [2]**

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| 9 UE procedure for reporting control information  < Unchanged parts are omitted >  A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE  - detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is not provided any of *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant, or  - is provided *uci-MuxWithDiffPrio*, or  - transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,  the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE  - previously detects a second DCI format scheduling the PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is provided *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, and  - is not provided *uci-MuxWithDiffPrio*, and  - transmits a repetition of a PUSCH transmission other than a first repetition,  the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format indicating a first resource for a PUCCH transmission in a slot, when  - the UE detects a second DCI format, in a PDCCH monitoring occasion that starts before the PDCCH monitoring occasion for the first DCI format, scheduling a PUSCH transmission in the slot, and  - the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and  - the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of and for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied, and  - if a second PUCCH resoruce is indicated by the last DCI format in a PDCCH monitoring occasion that starts before the monitoring occasion of the second DCI format, or configured for HARQ-ACK information corresponding to SPS PDSCH, and  - if the UE is not provided *enableDiffPUCCH-Resource*, the first resource for the PUCCH transmission is in the same time domain in the slot with the second PUCCH resource, and/or  - if the UE is not provided *enableDiffCB-Size*, the codebook size in the PUSCH transmission is expect unchanged even after including the HARQ-ACK information associated with the PDSCH reception scheduled by the first DCI format.  < Unchanged parts are omitted > |

**CR#3 in [3]**

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| 9 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE  - detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is not provided any of *enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant*, or  - is provided *uci-MuxWithDiffPrio*, or  - transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,  the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE  - previously detects a second DCI format scheduling the PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is provided *enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant*, or *enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant*, and  - is not provided *uci-MuxWithDiffPrio*, and  - transmits a repetition of a PUSCH transmission other than a first repetition in a slot,  the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format, in a first PDCCH monitoring occasion, indicating a first resource for a first PUCCH transmission in the slot, when  - the first resource overlaps with the repetition of the PUSCH transmission  - the PUSCH transmission is scheduled by a second DCI format in a second PDCCH monitoring occasion, and  - the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and  - the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of and for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied,  where  - the first PUCCH resource is same in the time domain as a second PUCCH resource that the UE determines for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource* and the first PDCCH monitoring occasion starts after the second PDCCH monitoring occasion, and  - the second PUCCH resource  - is indicated by the last DL DCI format in a third PDCCH monitoring occasion that starts no later than the second PDCCH monitoring occasion, or  - is for the PUCCH transmission with the HARQ-ACK information associated only with SPS PDSCHs activated by DCI formats in PDCCH monitoring occasions that start no later than the second PDCCH monitoring occasion  - the size of the HARQ-ACK codebook based on a DAI value of the second DCI format remains the same if the UE is not provided *enable-different-CBsize*. |

**Q1: Which CR (CR#1, CR#2, CR#3) above do you prefer and why?**

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| **Company** | **Which CR** | **Comment** |
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**Q2: If none of above CRs is preferred, please provide the suggested changes in the table below.**

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| **Company** | **Suggested Changes** |
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# 2nd round Discussion

## Companies’ view

Based on the output from Monday morning online discussion, following proposal is used for further discussed,

***Proposal****:*

*The changes in R1-2405256 is agreed in principle. The TP is to be further updated based on RRC parameters described in R1-2404946. Final CR in R1-240XXXX.*

To reflect the spirit of above proposal and make progress on the proposal, a TP is prepared as below. We can directly to discuss the TP.

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| 9 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE  - detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is not provided any of *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant, or  - is provided *uci-MuxWithDiffPrio*, or  - transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,  the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE  - previously detects a second DCI format scheduling the PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is provided *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, and  - is not provided *uci-MuxWithDiffPrio*, and  - transmits a repetition of a PUSCH transmission other than a first repetition in a slot,  the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format, in a first PDCCH monitoring occasion, indicating a first resource for a first PUCCH transmission in the slot, when  - the first resource overlaps with the repetition of the PUSCH transmission  - the PUSCH transmission is scheduled by a second DCI format in a second PDCCH monitoring occasion, and  - the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and  - the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of and for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied,  where  - the first PUCCH resource is same in the time domain as a second PUCCH resource that the UE determines for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource* and the first PDCCH monitoring occasion starts after the second PDCCH monitoring occasion, and  - the second PUCCH resource  - is indicated by the last DL DCI format in a third PDCCH monitoring occasion that starts no later than the second PDCCH monitoring occasion, or  - is for the PUCCH transmission with the HARQ-ACK information associated only with SPS PDSCHs activated by DCI formats in PDCCH monitoring occasions that start no later than the second PDCCH monitoring occasion  - the size of the HARQ-ACK codebook based on a DAI value of the second DCI format remains the same if the UE is not provided *enable-different-CBsize*. |

**Updated TP**

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| 9 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE  - detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is not provided any of *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant, or  - is provided *uci-MuxWithDiffPrio*, or  - transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,  the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE  - previously detects a second DCI format scheduling the PUSCH transmission in the slot, and  - multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.  If a UE  - is provided *enableType1HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType2HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, or *enableType3HARQ-ACK-MuxForDL-AssignmentAfterUL-Grant*, and  - is not provided *uci-MuxWithDiffPrio*, and  - transmits a repetition of a PUSCH transmission in a slot other than a first repetition,  the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format, in a first PDCCH monitoring occasion, indicating a first resource for a first PUCCH transmission in the slot, when  - the first resource overlaps with the repetition of the PUSCH transmission  - the PUSCH transmission is scheduled by a second DCI format in a second PDCCH monitoring occasion, and  - the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and  - the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of and for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied,  where  - the first PUCCH resource is same in the time domain as a second PUCCH resource that the UE determines for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource* and the first PDCCH monitoring occasion starts after the second PDCCH monitoring occasion, and  - the second PUCCH resource  - is indicated by the last DL DCI format in a third PDCCH monitoring occasion that starts no later than the second PDCCH monitoring occasion, or  - is for the PUCCH transmission with the HARQ-ACK information associated only with SPS PDSCHs activated by DCI formats in PDCCH monitoring occasions that start no later than the second PDCCH monitoring occasion  - UE expects the size of the HARQ-ACK codebook based on a DAI value of the second DCI format remains the same if the UE is not provided *enable-different-CBsize*.  \*\*\* Unchanged parts are omitted \*\*\* |

**Q3: Can you agree the TP above in Section 4.1? If not, please explain why.**

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| **Company** | **Agree or not** | **Comment** |
| ZTE |  | For PUSCH repetition type B, assuming two nominal repetitions scheduled in two slots and each slot has two actual repetitions, the current TP may imply that the TEI feature does NOT apply for the first repetition in the first slot and the first repetition in the second slot. We don’t think this is the intention. So, we suggest updating the following sequence as below  - transmits a repetition of a PUSCH transmission in a slot other than a first repetition ~~in a slot~~, |
| Apple |  | In the last sub-bullet, add “UE expects”, as of now it is not clear who should check the size remains the same, definitely it’s not UE’s job. gNB indicates and UE follows. |
| Moderator |  | Thanks for input, based on the comments from ZTE and Apple, I update a new TP above named “Updated TP”, the changes are with author name “Huawei\_v2”. Please keep commenting if you have and meanwhile, I also prepare a [draft CR](http://10.10.10.10/ftp/RAN/RAN1/Inbox/drafts/8.1(NR_WI)/NR_Others/TEI/Draft%20CR) in the draft folder with a cover page.  My plan is we discuss the draft CR directly on tomorrow online session. You can either comments here or update the draft CR with change marks and upload it directly to the draft folder. Thanks all for the efforts for make the spec clearer in advance. |
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# Conclusions

## Proposal for Monday online

***Proposal****: The changes in R1-2405256 is agreed in principle and update RRC parameters described in R1-2404946 in further.*

# References

1. R1-2404231 Correction on multiplexing HARQ-ACK in a PUSCH with repetitions ZTE
2. R1-2404946 Correction on HARQ-ACK multiplexing on a PUSCH repetition Huawei, HiSilicon
3. R1-2405256 Correction on multiplexing HARQ-ACK in a PUSCH with repetitions Samsung, Ericsson