**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,**AgreementIf 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. $T\_{proc,1}^{mux}$between the last PDSCH and PUCCH, $T\_{proc,2}^{mux}$ 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.
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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%3A%5C3gpp%5CMeetings%5CTSGR1%5CTSGR1_116%5CDocs%5CR1-2400675.zip) are supported by existing TEI agreements made in RAN1#115.

Case 2 in [R1-2400675](file:///C%3A%5C3gpp%5CMeetings%5CTSGR1%5CTSGR1_116%5CDocs%5CR1-2400675.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 $T\_{proc,1}^{mux}$ and $T\_{proc,2}^{mux}$ 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 $T\_{proc,1}^{mux}$ and $T\_{proc,2}^{mux}$ 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 $T\_{proc,1}^{mux}$ and $T\_{proc,2}^{mux}$ 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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# Conclusions

To be updated after discussion.

# 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