**3GPP TSG RAN WG1#116-bis R1-240xxxx**

**Changsha, Hunan Province, China, April 15th – 19th, 2024**

**Agenda item:** 8.4

**Source:** Moderator (Samsung)

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

**Document for:** Discussion and Decision

# Introduction

This contribution aims to collect and summarize company views on the Rel-18 TEI issue of multiplexing HARQ-ACK in a PUSCH as discussed in [1], [2] and [3].

Please consider entering the contact information below for better coordination for this discussion.

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# Background

In RAN1#115 meeting, the following agreement was made.

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| **Agreement**  **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. |

In RAN1#116 meeting, the following conclusion was made.

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| **Conclusion**   * The Case 1 and Case 2 in [R1-2400675](F:\\3GPP\\RAN1\\TSGR1_116b\\TEI\\Docs\\R1-2400675.zip) are supported by existing TEI agreements made in RAN1#115. * Case 2 in [R1-2400675](F:\\3GPP\\RAN1\\TSGR1_116b\\TEI\\Docs\\R1-2400675.zip) is supported with UE capability FG 55-4e. |

In [1], [2] and [3] Samsung and Ericsson discuss the remaining issues on scheduling a PDSCH after UL grant.

# Discussion

Two CRs are brought up by Samsung and Ericsson to capture the conclusion made in RAN#116b, respectively [2], [3].

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| CR#1 (Samsung) 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 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  - the UE does not expect to determine a different PUCCH resource in time domain for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource*, and  - if the UE is not provided *enable-different-CBsize*  - if based on a DAI value of the second DCI format the UE determines a first HARQ-ACK codebook, the UE does not expect to determine a second HARQ-ACK codebook that includes the HARQ-ACK information and has a different than the size of the first HARQ-ACK codebook  - else, the UE does not expect the first DCI format to schedule a PDSCH reception with TBs having enabled HARQ-ACK information that is reported in the slot.  \*\*\* Unchanged parts are omitted \*\*\* |

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| CR#2 (Ericsson)  9 UE procedure for reporting control information  \*\*\* Unchanged parts are omitted \*\*\*  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 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 the UE is not provided *enable-different-PUCCHresource*, the UE excepts the time domain allocation of the PUCCH resource for the HARQ-ACK information in the slot is the same as the time domain allocation of the PUCCH resource for the HARQ-ACK information associated to a PDSCH reception scheduled by a third DCI format, if the UE detects the third DCI format in a PDCCH monitoring occasion that ends before the PDCCH monitoring occasion for the second DCI format, and  - if the UE is not provided *enable-different-Cbsize*, the UE excepts the HARQ-ACK codebook size is the same as after including the HARQ-ACK information associated to a PDSCH reception scheduled by the first DCI format, if the UE detects a third DCI format in a PDCCH monitoring occasion that ends before the PDCCH monitoring occasion for the second DCI format.  \*\*\* Unchanged parts are omitted \*\*\* |
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Companies are encouraged to provide views on the CRs

**Q1: Do you agree with the spec change is necessary for the conclusion made in RAN1#116b?**

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| **Company** | **View** |
| QC | Open to discuss |
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Ericsson offline proposed to include the similar issue if the UE is not provided enable-different-PUCCHresource. CR#3 is proposed. The 5 sub-bullets should be satisfied if the UE multiplexes HARQ-ACK in the PUSCH, therefore, it only needs to clarify the cases for multiplexing. If a case is included, it is an error case.

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| CR#3 (offline comments from Ericsson) 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 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  - the UE determines a same PUCCH resource in time domain for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource*, and  - the UE determines a same size for the HARQ-ACK codebook after including the HARQ-ACK information if the UE is not provided *enable-different-CBsize*.  \*\*\* Unchanged parts are omitted \*\*\* |

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| CR#4 (offline comments from Ericsson) 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 first resource overlaps with the repetition of the PUSCH transmission  - 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  - the UE determines a second PUCCH resource in the same time domain for the PUCCH transmission with the HARQ-ACK information in the slot compared with the first resource if the UE is not provided *enable-different-PUCCHresource*, where 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 only for SPS PDSCHs, and  - the UE determines a same size for the HARQ-ACK codebook after including the HARQ-ACK information compared with the HARQ-ACK codebook without the HARQ-ACK information if the UE is not provided *enable-different-CBsize*.  \*\*\* Unchanged parts are omitted \*\*\* |
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**Q2: If the answer to Q1 is YES, which CR do you prefer?**

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| **Company** | **View** |
| QC | After a long discussion with E// we would like to propose the following alternative:  **First change** (to accommodate HARQ payload generated before and after the UL grant, not just after the UL grant):  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 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  **Second change** (to establish clear references for same/different PUCCH resource:  ~~the UE does not determine a different PUCCH resource in time domain for the PUCCH transmission with the HARQ-ACK information in the slot~~ if the UE is not provided enable-different-PUCCHresource, and   * the UE detects the third DCI format in a PDCCH monitoring occasion that ends before the PDCCH monitoring occasion for the second DCI format, and * the UE excepts the time domain allocation of the PUCCH resource for the HARQ-ACK information in the slot is the same as the time domain allocation of the PUCCH resource for the HARQ-ACK information associated to a PDSCH reception scheduled by a third DCI format   **Third change** (to establish clear references for same/different codebook sizes:  ~~the UE does not determine a different size for the HARQ-ACK codebook after including the HARQ-ACK information~~ if the UE is not provided enable-different-Cbsize, and   * if the UE detects a third DCI format in a PDCCH monitoring occasion that ends before the PDCCH monitoring occasion for the second DCI format, * the UE expects the HARQ-ACK codebook size is the same as after including the HARQ-ACK information associated to a PDSCH reception scheduled by the first DCI format. |
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# Conclusion

# Reference

[1] R1-2402449 Remaining issues on multiplexing HARQ-ACK in a PUSCH with repetitions Samsung

[2] R1-2402450 Corretion on multiplexing HARQ-ACK in a PUSCH with repetitions Samsung

[3] R1-2403401 Correction on multiplexing HARQ-ACK in a PUSCH with repetitions Ericsson