**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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| **Company** | **Contact(s)** | **Email address(es)** |
| Samsung (Moderator) | Sa Zhang | sa.zhang@samsung.com |
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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,**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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In RAN1#116 meeting, the following conclusion was made.

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| **Conclusion*** The Case 1 and Case 2 in R1-2400675 are supported by existing TEI agreements made in RAN1#115.
* Case 2 in R1-2400675 is supported with UE capability FG 55-4e.
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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 $T\_{proc,1}^{mux}$ 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 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 $T\_{proc,1}^{mux}$ 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 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 $T\_{proc,1}^{mux}$ 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 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 $T\_{proc,1}^{mux}$ 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 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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| CR#5 (offline comments from editor)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 $T\_{proc,1}^{mux}$ 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 UE determines a second PUCCH resource for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource*, where the second PUCCH resource is same in the time domain as the first PUCCH resource and - 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 same size with or without the HARQ-ACK information if the UE is not provided *enable-different-CBsize*.\*\*\* Unchanged parts are omitted \*\*\* |

**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 $T\_{proc,1}^{mux}$ and $T\_{proc,2}^{mux}$ for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied, and**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