**3GPP TSG RAN WG1 #117 R1-2405596**

**Fukuoka City, Fukuoka, Japan, May 20th – 24th, 2024**

**Agenda item: 7**

**Source:** Moderator (Samsung)

**Title:** Summary #2 of discussion on multiple DAI values for a UL DCI format

**Document for:** Discussion and Decision

# Introduction

This contribution aims to collect and summarize company views on the multiple DAI values as discussed in [1] and [2].

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

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# Background

In [1], Samsung points out that the following agreement made in RAN1#109 meeting was not correctly captured in the specifications.

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| Agreement  For Rel-16 UEs, in the scenario with more than one PUSCH (overlapping and non-overlapping) and no overlapping PUCCH with HARQ-ACK within a span on one PUCCH slot (both single carrier and UL CA), for a unified design, the following should be specified:   1. Selection of the candidate PUSCH for multiplexing: PUSCHs without UL-TDAI=4 in case Type 2 CB, and without UL-TDAI n.e. 1 in case of Type 1 CB within the PUCCH slot are candidates 2. Prioritization rules to select PUSCH for multiplexing. Prioritization rules are identical to 38.213 3. Limitations for multiplexing    * UE expects to multiplex HARQ-ACK on only 1 PUSCH selected based on step 2 in the PUCCH slot.    * All the PUSCHs in the determined candidate set after step 1 have to satisfy Rel-15 UCI multiplexing timeline, defined with respect the starting symbol of the earliest PUSCH transmission in the candidate set.   The above specified behavior is supported subject to a new Rel-16 UE capability [xxxxx]   * FFS: the details of the capability signaling |

The highlighted yellow text below would result in misalignment between UE and gNB on whether HARQ-ACK should be multiplexed in a PUSCH.

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| 9 UE procedure for reporting control information  …  When a UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the multiple PUSCHs overlap with a PUCCH carrying UCI in the slot, the UE selects all the PUSCHs overlapping with the PUCCH as the candidate PUSCHs for UCI multiplexing within the slot.  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that includes a DAI field that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*.  … |

An example is given in Figure 1 to illustrate the issue. According to the highlighted text, the UE does not multiplex HARQ-ACK information in the PUSCH because the UL DCI formats indicates a DAI value of 4.



**Figure 1**

The issue was discussed in RAN1#116bis meeting and the following conclusion was made.

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| **Conclusion**  The proposal in R1-2403707 can be discussed at a future meeting for Rel-17 or Rel-18. |

# Discussion

## 1st round discussion

The following CR is proposed in [2].

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| CR#1 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for the single PUSCH or any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that includes a DAI field that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static* if the total number of bits for all DAI fields for unicast is no larger than 2, else,   * the value indicated by the first DAI field [5, TS 38.212] is equal to 0 if the number of bits for the first DAI field is 1 bit; else, each value indicated by the first DAI field is equal to 4, and, * each value indicated by the second DAI field [5, TS 38.212] is equal to 4, if any, and * the value indicated by the third DAI field [5, TS 38.212] is equal to 0 if the number of bits for the third DAI field is 1 bit; else, each value indicated by the third DAI field is equal to 4, if any.   \*\*\* Unchanged parts are omitted \*\*\* |

The following offline comments are received.

* Remove “the single PUSCH or”
* Replace “includes a DAI filed” with “indicates a DAI value” to be consistent with the other description in the spec
* Change the “if condition” to be “If the DCI format indicates one DAI value”
* Add a new UE capability to support the CR.

The following proposal is made based on the received comments.

**Proposal 1: Adopt CR#2 in Rel-18 TS 38.213 with a new UE capability.**

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| CR#2 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static* if the DCI format indicates only one DAI value, else,   * the value indicated by the first DAI field [5, TS 38.212] is equal to 0 if the number of bits for the first DAI field is 1 bit; else, each value indicated by the first DAI field is equal to 4, and, * each value indicated by the second DAI field [5, TS 38.212] is equal to 4, if any, and * the value indicated by the third DAI field [5, TS 38.212] is equal to 0 if the number of bits for the third DAI field is 1 bit; else, each value indicated by the third DAI field is equal to 4, if any.   \*\*\* Unchanged parts are omitted \*\*\* |

**Q1: Do you support Proposal 1?**

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| **Company** | **View** |
| Apple | “if any” on the second sub-bullet must be removed since everything under the first “else” corresponds to more than 1 DAI value in DCI  It is not easy to check the flow, we prefer the existing simpler version. Otherwise we have to check for what use cases we have more than 2 DAI bit-fields in UL DCI, for each use-case what is the size of the additional DAI field?  Same question for 3 DAI values in DCI? |
| Mod | The reason of “if any” is because it is possible there may be two values of the 1st DAI field and the 2nd or 3rd DAI field may not exist. For example, 4 bits indicates two DAI values based on the definition of the DAI value which is indicated by 2 bits.   |  | | --- | | - 1st downlink assignment index - 1, 2 or 4 bits: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Table 9.1.3-2: Value of DAI   |  |  |  | | --- | --- | --- | | DAI MSB, LSB |  | Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH indicating SPS PDSCH release or providing TCI state update or DCI format 1\_1 or DCI format 1\_3 indicating SCell dormancy without scheduling a PDSCH reception is present, or number of PDCCH monitoring occasions associated with PDCCH for scheduling PDSCH receptions on more than one cells, denoted as and | | 0,0 | 1 |  | | 0,1 | 2 |  | | 1,0 | 3 |  | | 1,1 | 4 |  | | |
| Nokia | In our view a CR is needed, and the proposed CR looks technically correct  If a UE capability were to be introduced, it is unclear what that would the capability description be, and what would be the implication to features introduced the 2nd and 3rd DAI fields if the capability was not indicated by the UE. Furthermore, an additional RRC configuration for this capability would seem odd. What does that parameter enable?  I am sorry for not realizing the difference between a DAI value and a DAI field. Would the following simplification work?  …except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 for all the DAI values for all the DAI fields in the DCI in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 for all the DAI values for all the DAI fields in the DCI in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static.* |
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## 2nd round discussion

There are three options based on the online discussion.

Option 1: Adopt CR#2 without a NEW UE capability.

Option 2: Adopt CR#3 with a NEW UE capability without a corresponding new RRC parameter.

Option 3: Adopt CR#4 with a NEW UE capability and a corresponding new RRC parameter.

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| CR#3 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static* if the DCI format indicates only one DAI value, or, if UE indicates the capability [*mux-HARQ-ACK-withoutPUCCH-onPUSCH-multi-UL-DAI*] and,   * the value indicated by the first DAI field [5, TS 38.212] is equal to 0 if the number of bits for the first DAI field is 1 bit; else, each value indicated by the first DAI field is equal to 4, and, * each value indicated by the second DAI field [5, TS 38.212] is equal to 4, if any, and * the value indicated by the third DAI field [5, TS 38.212] is equal to 0 if the number of bits for the third DAI field is 1 bit; else, each value indicated by the third DAI field is equal to 4, if any.   \*\*\* Unchanged parts are omitted \*\*\* |

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| CR#4 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static* if the DCI format indicates only one DAI value, or, if the UE is provided [*enable*-*mux-HARQ-ACK-withoutPUCCH-onPUSCH-multi-UL-DAI*] and,   * the value indicated by the first DAI field [5, TS 38.212] is equal to 0 if the number of bits for the first DAI field is 1 bit; else, each value indicated by the first DAI field is equal to 4, and, * each value indicated by the second DAI field [5, TS 38.212] is equal to 4, if any, and * the value indicated by the third DAI field [5, TS 38.212] is equal to 0 if the number of bits for the third DAI field is 1 bit; else, each value indicated by the third DAI field is equal to 4, if any.   \*\*\* Unchanged parts are omitted \*\*\* |

**Q2: Please share your views on the three options**

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I think Nokia provides a good direction to move forward, companies are encouraged to check the CR#5.

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| CR#5 UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*   * If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 for each DAI value indicated by 2 bits, if any,, and is equal to 0 for each DAI value indicated by 1 bit, if any.   \*\*\* Unchanged parts are omitted \*\*\* |

**Q3: Can you live with CR#5?**

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# Conclusion

The following is proposed based on the discussion.

Proposal: Adopt the following TP for Rel-18 TS 38.213.

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| UE procedure for reporting control information \*\*\* Unchanged parts are omitted \*\*\*  If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that indicates a DAI value that is equal to 4 for each DAI value indicated by 2 bits, if any, and is equal to 0 for each DAI value indicated by 1 bit, if any.  \*\*\* Unchanged parts are omitted \*\*\* |

# Reference

1. R1-2404067 Discussion on multiplexing HARQ-ACK in a PUSCH transmission Samsung
2. R1-2404068 Correction on multiplexing HARQ-ACK in a PUSCH transmission Samsung