**3GPP TSG-RAN WG1 Meeting #105-eR1-210xxxx**

**e-Meeting, May 10th – 27th, 2021**

**Agenda item:** **7.1**

**Source: Moderator (Apple Inc.)**

**Title: Summary of email discussion [105-e-NR-7.1CRs-13] on the correction for HARQ-ACK timing in Rel-16**

**Document for: Discussion and Decision**

# 1 Introduction

This contribution provides the summary for the following email discussion in RAN1#105-e:

**Issue#28**

[R1-2105075](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_105%5CDocs%5CR1-2105075.zip) Correction for HARQ-ACK timing in Rel-16 Apple, Ericsson

[105-e-NR-7.1CRs-13] Issue#28: Correction for HARQ-ACK timing in Rel-16 – Sigen (Apple) by May 25

* For Rel-16 only

Section 2 provides the background information. Section 3 captures the detailed email discussions. Section 4 summarizes the outcome of the email discussion.

# 2 Background

For HARQ-ACK, the PUCCH for HARQ-ACK is transmitted in UL slot *n+k*, where *k* is indicated in UL DCI, and *n* is determined based on PDSCH. When UL SCS is larger than DL SCS, two different interpretations existed in the history of RAN1 discussions. The issue was further discussed in RAN1#104b-e [1], and it was concluded that two different interpretations can exist in Rel-15, but it is important to achieve a common understanding for Rel-16.

***Conclusion:***

*For HARQ-ACK timing in Rel-15, in case UL SCS is larger than DL SCS, there are two different interpretations:*

*-       Interpretation 1: k = 0 corresponds to the last UL slot that overlaps with the PDSCH*

*-       Interpretation 2: k = 0 corresponds to the last UL slot that overlaps with the DL slot for the PDSCH*

*Further discuss this issue for Rel-16 in future meetings.*

Assuming an example as shown in Fig. 1 where DL uses 15 kHz SCS and UL uses 30 kHz SCS, with interpretation 1 *k*=0 would correspond to UL slot 6, while with interpretation 2 *k*=0 would correspond to UL slot 7.



Figure 1 Example of HARQ-ACK timing

The following point was raised in [2]:

“Purely from HARQ-ACK timing perspective, adopting either interpretation seems to be fine, except that interpretation 2 is aligned with the original agreement.

However, for the pseudo-code for the Type-1 HARQ-ACK codebook construction to work properly, interpretation 2 should be adopted. Basically, the highlighted part below only makes sense if the end of DL slot for PDSCH is used as the reference.”

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| **Excerpt from TS 38.213 Clause 9.1.2.1**Graphical user interface, text, application  Description automatically generated |

Due to the above reason, it was proposed in [2] to adopt interpretation 2 and a corresponding TP was provided.

To better understand the issue for Type 1 HARQ-ACK codebook with interpretation 1, a very simple example is provided in Figure 2.



Figure 2 An example of Type-1 HARQ-ACK codebook construction for K1 set = {1}

In this example, it is assumed that the set of K1 values is {1} (i.e. consisting of a single value).

According to interpretation 1,

* for PDSCH1, K1=1 means that the HARQ-ACK should be provided in UL slot 7 (e.g. PUCCH1). For PDSCH2, K1=1 means that the HARQ-ACK should be provided in UL slot 8 (e.g. PUCCH2).
* However, if we follow the pseudo code for Type-1 HARQ-ACK codebook construction, for the HARQ-ACK codebook constructed in UL slot 7, as the highlighted condition is not satisfied (i.e., mod(7-1+1, 2) is not 0), there is not any DL slot that would have HARQ-ACK mapped to UL slot 7.
* On the other hand, for HARQ-ACK codebook constructed in UL slot 8, as the highlighted condition is satisfied, the TDRA entries in DL slot 3 would have HARQ-ACK mapped to UL slot 8, even though PDSCH1 cannot indicate HARQ-ACK in slot 8 with K1=1.

This means that the HARQ-ACK for PDSCH1 is lost in the codebook construction, and the UE would never transmit it to the gNB.

With interpretation 2, such an issue does not exist.

# 3 Email Discussions

## 3.1 First Round of Email Discussion

It is very important for RAN1 to conclude on a single interpretation for the HARQ-ACK timing in Rel-16, in order to support the case when UL SCS is larger than DL SCS. Companies are invited to provide their views on which interpretation should be adopted for Rel-16 and the reasoning behind it (taking into account the issue of Type-1 HARQ-ACK codebook discussed in Section 2).

**Companies please indicate which interpretation you support for Rel-16.**

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| **Interpretation 1** |  |
| **Interpretation 2** | Qualcomm, OPPO, Nokia, NSB, Huawei, HiSilicon, ZTE, MediaTek, CATT (at least for slot based HARQ-ACK feedback), WILUS, Ericsson, LG, Intel, Samsung, Apple |

**Companies please provide detailed reasons why you support interpretation 1 or 2.**

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| **Company** | **Comments** |
| Qualcomm | The slot of the PDSCH reception is the reference for k=0, rather than the actual PDSCH symbols due to the reasons we have discussed in the last meeting. At least from Rel-16 spec, we should have a reasonable common interpretation.  |
| OPPO | Although we agree in principle with what the draft CR proposed, we are a bit confused by the example given in background section. In this example, because K1={1}, then any nU that is odd number would not meet the condition of mod(nU-K1+1, 2)=0. This failure seems more related to the setup of K1, because if another assumption is made on K1, such as K1={only even number(s)}, any nU that is even number would not meet the condition of mod(nU-K1+1, 2)=0, which means the situation flips between UL slot 7 and UL slot 8. The given example does not seem quite relevant to the justification of either interpretation. [Moderator] Type-1 CB construction procedure should work regardless of the set of values configured for K1. The intention of the example is to show that in some cases Type-1 CB construction does not work properly for interpretation 1. I understand that there can be some other cases that Type-1 CB can be constructed properly even with interpretation 1, but the point is that this is not true for all cases. Interpretation 2 does not have such an issue. Anyway, since companies understand the issue well, the example is not important. |
| Nokia, NSB | Agree with Qualcomm. |
| Huawei, HiSilicon | This issue has been discussed extensively at the last meeting. Even though there are different views for Rel-15, the original intention is clear enough and should be clarified in Rel-16. |
| ZTE | Share the view with Qualcomm. |
| MediaTek | Agree with Qualcomm. |
| CATT | We would like to clarify how to understand interpretation 2 for sub-slot based HARQ-ACK feedback. |
| WILUS | As we discussed in the last RAN1 meeting, interpretation 2 is more aligned to the original intention of the agreements. For the sub-slot based HARQ-ACK feedback, our understanding is that the UL slot is replaced by the UL sub-slot in interpretation 2, i.e, *k = 0 corresponds to the last UL (sub-)slot that overlaps with the DL slot for the PDSCH.*  |
| Ericsson | We share the same reasoning as Qualcomm.With respect to comments from CATT and WILUS, we share the same view and addition by WILUS clarifies the interpretation 2 more precisely.However, in our view the change is more related on the DL side. The same principle as before for UL is applied in case of slot/sub-slot for UL. |
| LG | We also agree with QC and other companies, and are also fine with the clarification from WILUS. |
| Intel | Support Interpretation 2 for the reasons mentioned above. |
| Samsung | We support Interpretation 2, and have the same concern from CATT |
| Apple | Support interpretation 2 |

## 3.2 Second Round of Email Discussion

During the first round of the discussion, all the companies support interpretation 2. The only issue raised is the understanding for sub-slot-based HARQ-ACK feedback. For the companies that had provided views, they think “sub-slot” should replace “slot” in this case.

Therefore, Proposal 1 is proposed below. The reason that “in case UL SCS is larger than DL SCS” is not included in the proposal is to accommodate the case with sub-slot-based HARQ-ACK feedback. However, it does not really change the intention of the proposal because in case UL SCS is smaller than or equal to DL SCS, for slot-based HARQ-ACK feedback, interpretation 2 is already the case anyway.

### Proposal 1:

**For HARQ-ACK timing in Rel-16,**

* ***k* = 0 corresponds to the last UL slot that overlaps with the DL slot for the PDSCH for slot-based HARQ-ACK feedback.**
* ***k* = 0 corresponds to the last UL sub-slot that overlaps with the DL slot for the PDSCH for sub-slot-based HARQ-ACK feedback.**

**Companies please provide comments on Proposal 1.**

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| **Company** | **Comments** |
| CATT | The agreement in RAN1#97 for sub-slot based HARQ-ACK feedback is as follows.Agreements:For sub-slot-based HARQ-ACK feedback procedure, K1 is the number of sub-slots from the sub-slot containing the end of PDSCH to the sub-slot containing the start of PUCCH. * Use UL numerology to define the sub-slot grid for PDSCH-to-sub-slot association.
* FFS: The configurable value range of K1 needs to be extended, and impact to related DCI field bitwidth.
* Note: It has been agreed that K1 is defined following R15 approach but in unit of sub-slot.

With proposal 1, the previous agreement is reverted and the latency for HARQ-ACK feedback is increased as shown in the figure below. We think more discussion is needed involving URLLC delegates and it may not be appropriate to revert the agreement here. |
| Samsung | We share the same view with CATT. If interpretation 2 is adopted for the case with sub-slot based HARQ-ACK feedback, there will be latency issue for URLLC HARQ-ACK.  |

(Please do not further comment on Proposal 1.)

Based on the feedback above, some companies prefer not to take the similar approach for sub-slot-based HARQ-ACK feedback as for slot-based HARQ-ACK feedback. Therefore, the proposal is updated to address slot-based HARQ-ACK feedback only, while input is collected below for slot-based HARQ-ACK feedback.

### Proposal 1a:

**For HARQ-ACK timing in Rel-16 with slot-based HARQ-ACK feedback,** **in case UL SCS is larger than DL SCS, *k* = 0 corresponds to the last UL slot that overlaps with the DL slot for the PDSCH.**

**Companies please provide comments on Proposal 1a.**

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| **Company** | **Comments** |
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The TP proposed in [2] can be used as the starting point for discussion. How to handle sub-slot-based HARQ-ACK feedback will be addressed after we reach an agreement on the issue.

### Proposal 2:

**Adopt the following TP for TS 38.213 for Rel-16:**

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| **TP for TS 38.213**9.1.2 Type-1 HARQ-ACK codebook determinationThis Clause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*.A UE reports HARQ-ACK information for a corresponding PDSCH reception or SPS PDSCH release only in a HARQ-ACK codebook that the UE transmits in a slot indicated by a value of a PDSCH-to-HARQ\_feedback timing indicator field in a corresponding DCI format. The UE reports NACK value(s) for HARQ-ACK information bit(s) in a HARQ-ACK codebook that the UE transmits in a slot not indicated by a value of a PDSCH-to-HARQ\_feedback timing indicator field in a corresponding DCI format. If a UE is not provided *pdsch-HARQ-ACK-OneShotFeedback*, the UE does not expect to receive a PDSCH scheduled by a DCI format that the UE detects in any PDCCH monitoring occasion and includes a PDSCH-to-HARQ\_feedback timing indicator field providing an inapplicable value from *dl-DataToUL-ACK-r16*.If the UE is provided *pdsch-AggregationFactor-r16* in *SPS-Config* or *pdsch-AggregationFactor* in *PDSCH-Config* and no entry in *pdsch-TimeDomainAllocationList* and *pdsch-TimeDomainAllocationListDCI-1-2* includes *repetitionNumber* in *PDSCH-TimeDomainResourceAllocation-r16*, $N\_{PDSCH}^{repeat,max}$ is a maximum value of *pdsch-AggregationFactor-r16* in *SPS-Config* or *pdsch-AggregationFactor* in *PDSCH-Config*; otherwise $N\_{PDSCH}^{repeat,max}=1$. The UE reports HARQ-ACK information for a PDSCH reception- from DL slot $n\_{D}-N\_{PDSCH}^{repeat}+1+1$ to DL slot $n\_{D}$, if $N\_{PDSCH}^{repeat}$ is provided by *pdsch-AggregationFactor* or *pdsch-AggregationFactor-r16* [6, TS 38.214], or - from DL slot $ n\_{D}-repetitionNumber+1$ to DL slot $n\_{D}$, if the time domain resource assignment field in the DCI format scheduling the PDSCH reception indicates an entry containing *repetitionNumber,* or - in DL slot $n\_{D}$, otherwise only in a HARQ-ACK codebook that the UE includes in a PUCCH or PUSCH transmission in slot $n+k$, where $n$ is the last slot based on the UL SCS overlapping with DL slot $n\_{D}$ and $k$ is a number of slots indicated by the PDSCH-to-HARQ\_feedback timing indicator field in a corresponding DCI format or provided by *dl-DataToUL-ACK* if the PDSCH-to-HARQ\_feedback timing indicator field is not present in the DCI format. If the UE reports HARQ-ACK information for the PDSCH reception in a slot other than slot $n+k$, the UE sets a value for each corresponding HARQ-ACK information bit to NACK. < Unchanged parts are omitted >9.2.3 UE procedure for reporting HARQ-ACKA UE does not expect to transmit more than one PUCCH with HARQ-ACK information in a slot per priority index, if the UE is not provided *ackNackFeedbackMode = separate*. For DCI format 1\_0, the PDSCH-to-HARQ\_feedback timing indicator field values map to {1, 2, 3, 4, 5, 6, 7, 8}. For a DCI format, other than DCI format 1\_0, scheduling a PDSCH reception or a SPS PDSCH release, the PDSCH-to-HARQ\_feedback timing indicator field values, if present, map to values for a set of number of slots provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACKForDCIFormat1\_2*, as defined in Table 9.2.3-1. For a SPS PDSCH reception ending in slot , the UE transmits the PUCCH in slot $n+k$ where $k$ is provided by the PDSCH-to-HARQ\_feedback timing indicator field, if present, in a DCI format activating the SPS PDSCH reception. If the UE detects a DCI format that does not include a PDSCH-to-HARQ\_feedback timing indicator field and schedules a PDSCH reception or activates a SPS PDSCH reception ending in slot $n$, the UE provides corresponding HARQ-ACK information in a PUCCH transmission within slot $n+k$ where $k$ is provided by *dl-DataToUL-ACK*, or *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACKForDCIFormat1\_2*.With reference to slots for PUCCH transmissions, if the UE detects a DCI format scheduling a PDSCH reception ending in slot $n$ or if the UE detects a DCI format indicating a SPS PDSCH release or indicating SCell dormancy through a PDCCH reception ending in slot $n$, or if the UE detects a DCI format that requests Type-3 HARQ-ACK codebook report and does not schedule a PDSCH reception through a PDCCH reception ending in slot $n$, as described in Clause 9.1.4, the UE provides corresponding HARQ-ACK information in a PUCCH transmission within slot $n+k$, where $k$ is a number of slots and is indicated by the PDSCH-to-HARQ\_feedback timing indicator field in the DCI format, if present, or provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACKForDCIFormat1\_2*. $k=0$ corresponds to the last slot based on the UL SCS that overlaps with the DL slot for PDSCH reception or the PDCCH reception in case of SPS PDSCH release or in case of SCell dormancy indication or in case of the DCI format that requests Type-3 HARQ-ACK codebook report and does not schedule a PDSCH reception. < Unchanged parts are omitted > |

**Companies please provide comments on Proposal 2.**

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| **Company** | **Comments** |
| Samsung | We generally ok with the TP. But the meaning of ‘based on the UL SCS’ needs to be clarified, because it seems interpretation 2 is adopted only for the case when UL SCS is larger than DL SCS. So we suggest to remove ‘based on the UL SCS’. |
| CATT | With this TP, when sub-slot is configured, interpretation 2 applies. As commented for proposal 1, more discussion is needed for sub-slot based HARQ-ACK transmission. In addition, we think “based on the UL SCS” is equivalent to “of the PUCCH transmission”. As discussed in Rel-15, the intention is to follow the SCS of PUCCH. So there is no need to change this part. |

### Sub-slot-based HARQ-ACK feedback

**For HARQ-ACK timing in Rel-16 with sub-slot-based HARQ-ACK feedback,**

* **Option 1: *k* = 0 corresponds to the last UL sub-slot that overlaps with the PDSCH.**
* **Option 2: *k* = 0 corresponds to the last UL sub-slot that overlaps with the DL slot for the PDSCH.**

**Companies please indicate which option you support for sub-slot-based HARQ-ACK feedback.**

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| **Option 1** |  |
| **Option 2** |  |

**Companies please provide detailed comments.**

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| **Company** | **Comments** |
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# 4 Outcome of the Email Discussion

# References

1. R1-2104105, Summary of email discussion [104b-e-NR-7.1CRs-04] on the correction for HARQ-ACK timing, Moderator (Apple Inc.), RAN1#104b-e, April 2021.
2. R1-2105075, Correction for HARQ-ACK timing in Rel-15 and Rel-16, Apple, Ericsson, RAN1#105-e, May 2021.