**3GPP TSG-RAN WG1 Meeting #106-eR1-210xxxx**

**e-Meeting, August 16th – August 27th, 2021**

**Agenda item:** **7.2.5**

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

**Title: Summary of email discussion [106-e-NR-L1enh-URLLC-03] on sub-slot-based 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#106-e:

* [106-e-NR-L1enh-URLLC-03] Issue#7: HARQ-ACK timing for sub-slot based HARQ-ACK feedback by August 20 – Sigen (Apple)

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. This was discussed in RAN1#104b-e [1] and RAN1#105-e [2], and it was concluded that the two different interpretations can exist in Rel-15, but for Rel-16, a working assumption was made to adopt interpretation 2 below. The main reasons for adopting interpretation 2 are that it is aligned with earlier RAN1 agreement and it is also aligned with the Type-1 HARQ-ACK codebook construction in TS 38.213.

***Conclusion:*** *(RAN1#104b-e)*

*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.*

***Working Assumption*** *(RAN1#105-e)*

*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.*

* *Further discuss the HARQ-ACK timing for sub-slot-based HARQ-ACK feedback*
* *FFS specification impact*

What remains open is the HARQ-ACK timing for sub-slot-based HARQ-ACK feedback. As discussed in [2], similar to slot-based HARQ-ACK feedback, two options are available:

*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.*

Option 1 is aligned with the following RAN1#97 agreement, while Option 2 is aligned with the working assumption that was made for slot-based HARQ-ACK timing in RAN1#105-e.

*Agreements: (RAN1#97)*

*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.*

This issue was discussed in [3]-[6] submitted to RAN1#106-e. A draft CR is also provided in [3].

Option 2 is preferred in [3][6], while Option 1 is preferred in [4][5]. The arguments for each option are summarized as follows:

* Option 1
  + Reduced latency in some cases (e.g. when PDSCH is at the beginning of the DL slot and the earliest symbols for HARQ-ACK feedback are UL symbols) compared to Option 2, as shown in Figure 1.
* Option 2
  + Consistent behavior between slot-based and sub-slot-based HARQ-ACK feedback timing
  + Principle of Type 1 HARQ-ACK codebook construction can be reused for sub-slot-based HARQ-ACK feedback.
  + Less gNB/UE complexity and less specification impact

Diagram

Description automatically generated

Figure 1 *k = 0* for Option 1 and Option 2

# 3 Email Discussions

## 3.1 First Round of Email Discussion

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.**

|  |  |
| --- | --- |
| **Option 1** | Nokia/NSB, Qualcomm, OPPO |
| **Option 2** |  |

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

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| **Company** | **Comments** |
| Nokia, NSB | Option 1 to have the reduced latency. We should not forget that the main motivation in Rel-16 to introduce sub-slot PUCCH actually was to reduce the HARQ-ACK latency which would be now lost.  Actually, we don’t think that option one creates more specification changes as actually the current specs describe Option 1 (so changes will be needed for the slot-based decision, not the other way around)!  On the Type 1 CB, we anyhow need changes there so also here we don’t think there is a need for much different handling – moreover, this is not existing specifications yet (see AI 8.3.1.1 where we introduce this now in Rel-17) |
| Qualcomm | We support Option 1. As pointed out by Nokia, Option 1 is what we agreed in RAN1 Rel-16 URLLC, and is what’s been implemented in the spec (TS 38.213, v16.6.0).  On the type-1 CB, Rel-16 doesn’t support sub-slot based Type-1 HARQ-ACK CB. So we are not sure why this should be taken into account for a Rel-16 CR discussion (at this late stage). |
| OPPO | We support option 1. As commented by Nokia and QC, option 1 can reduce the HARQ feedback latency, which is the intention to introduce sub-slot based HARQ-ACK feedback in Rel-16. And we share similar view with QC that Rel-16 does not support sub-slot based Type-1 HARQ-ACK CB so some changes (if needed) can leave to Rel-17 HARQ-ACK AI. |
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The TP for both slot-based and sub-slot-based HARQ-ACK feedback will be discussed together after this issue is concluded.

## 3.2 Second Round of Email Discussion

# 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. R1-2106301, Summary of email discussion [105-e-NR-7.1CRs-13] on the correction for HARQ-ACK timing in Rel-16, Moderator (Apple Inc.), RAN1#105-e, May 2021.
3. R1-2107063, Draft CR on Timing for slot-based and sub-slot-based HARQ-ACK Feedback, Ericsson, RAN1#106-e, Aug. 2021.
4. R1-2107266, Remaining issues on HARQ-ACK timing for sub-slot based HARQ-ACK feedback, OPPO, RAN1#106-e, Aug. 2021.
5. R1-2107681, Correction for HARQ-ACK timing in Rel-16, Huawei, HiSilicon, RAN1#106-e, Aug. 2021.
6. R1-2107713, Discussions on HARQ-ACK timing for sub-slot-based HARQ-ACK feedback in Rel-16, Apple, RAN1#106-e, Aug. 2021.