**3GPP TSG RAN WG1 #106-e R1-210xxxx**

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

**Agenda Item:** 7.2.5

**Source:** LG Electronics

**Title:** Summary for email discussion [106-e-NR-L1enh-URLLC-10]

**Document for:** Discussion and decision

# Introduction

According to discussion at the preparation phase, the following email thread is allocated by Chairman for further discussion:

[106-e-NR-L1enh-URLLC-10] Issue#16: multi-CSI-PUCCH-ResourceList where SPS HARQ-ACK multiplexed by August 20 - Duckhyun (LG)

This email discussion has been triggered by following contributions:

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| [**R1-2106488**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106488.zip) | CSI-PUCCH-ResourceList where SPS HARQ-ACK multiplexed | Huawei, HiSilicon |
| [**R1-2106677**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106677.zip) | Multi-CSI-PUCCH-ResourceList with Multiplexed SPS HARQ-ACK | Ericsson |
| [**R1-2106826**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106826.zip) | Draft CR] Clarification on Inter-sub-slot multiplexing of low-priority UCIs | Nokia, Nokia Shanghai Bell |
| [**R1-2107557**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107557.zip) | Discussion on Nokia draft CRs on Rel-16 URLLC/IIoT Scheduling/HARQ and SPS enhancements | Nokia, Nokia Shanghai Bell |
| [**R1-2107983**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107983.zip) | Maintenance on SPS enhancements | vivo |

The issue of “multi-CSI-PUCCH-ResourceList where SPS HARQ-ACK multiplexed” had been discussed in the previous meetings. Related email discussion and progress can be found in R1-2106358.

# Summary of contributions and E-mail Discussion

The main discussion point is whether it is allowed to multiplex SPS HARQ-ACK into another sub-slot. If UE is configured with SPS to use sub-slot based HARQ-ACK codebook, SPS HARQ-ACK PUCCH would be able to be multiplexed with other PUCCH. According to current specification, SPS HARQ-ACK bit can be multiplexed into PUCCH resources in multi-CSI-PUCCH-ResourceList, which is specified as ‘slot-based PUCCH’. Thus, there could be a case that sub-slot-based HARQ-ACK bit is multiplexed into PUCCH resource which is not specified as ‘sub-slot-based’.

Followings are related proposals including draft CR in this meetings

From R1-2106488

* + **Issue #3-1: Whether it is allowed to multiplex SPS HARQ-ACK into another sub-slot?**

***Proposal 1: Conclude that***

***For the multiplexing among overlapping channels with same a given priority index, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing.***

* + **Issue #3-2: Whether it is allowed to multiplex SR into another sub-slot?**

***Observation 1: The reason for the restriction to configure PUCCH resources carrying SR or CSI within the sub-slot is to avoid an overlap between CSI/SR PUCCH resources and multiple HARQ-ACKs in different sub-slots with the same priority index.***

***Proposal 2: It is allowed to multiplex SR into another sub-slot.***

* + **Issue #3-3: Whether it is allowed to multiplex SPS HARQ-ACK in a sub-slot with other PUCCH transmission in different sub-slot?**

***Observation 2: If it is allowed to multiplex SR into another sub-slot, it is naturally allowed to multiplex SPS HARQ-ACK in a sub-slot with other PUCCH transmission in different sub-slot.***

From R1-2106677

* Reason for change
  + In Rel-16, HARQ-ACK can be configured with sub-slot based PUCCH transmission. When multi-CSI-PUCCH-ResourceList is configured, and CSI is to be multiplexed with HARQ-ACK corresponding only to SPS PDSCH(s), the existing specification allows that the HARQ-ACK in one sub-slot is moved to a different sub-slot after multiplexing. If this happens, there is no procedure to multiplex two HARQ-ACK codebooks, i.e., one HARQ-ACK CB that naturally reside in the new slot, and another HARQ-ACK CB that’s moved in.
* Summary of change:
  + It is clarified that, when multi-CSI-PUCCH-ResourceList is configured, and CSI is to be multiplexed with HARQ-ACK corresponding only to SPS PDSCH(s), the UE does not expect that the HARQ-ACK in one sub-slot is moved to a different sub-slot after multiplexing.

From R1-210682:

* Reason for change
  + Based on the current specifications, inter-sub-slot multiplexing of low-priority UCIs may occur when sub-slot HARQ-ACK is involved. And this could create ambiguities since the current procedure to determine the final PUCCH resource (for multiplexing) is applied per sub-slot.
* Summary of change:
  + Clarify that for the multiplexing among overlapping LP PUCCHs, if a UE is provided subslotLengthForPUCCH for the LP PUCCH-Config, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) and/or SR in one sub-slot is moved to a different sub-slot after multiplexing.
  + Adding following text to TS 38.213 claus 9.
    - If a UE is provided one or two PUCCH-Config and provided subslotLengthForPUCCH in the PUCCH-Config or in the first PUCCH-Config, respectively, the UE does not expect that at least one of HARQ-ACK of priority index 0 corresponding to PDSCH reception without a corresponding PDCCH or SR of priority index 0 in one sub-slot is moved to a different sub-slot after UE multiplexes UCIs of priority index 0.

From R1-2107557:

On Issue 3-1, companies somewhat agreed that the UE shouldn’t expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing. In that regard, the following FL proposal could be supported:

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| **Original FL Proposal 3**  **For the multiplexing among overlapping channels with same a given priority index, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing.** |

From R1-2107983:

In the previous meetings, the issue of multiplexing of SPS HARQ-ACK and CSI was discussed. For the PUCCH resources configured for CSI and SR are slot level, when SPS HARQ-ACK are multiplexed with CSI on a PUCCH resource configured by *multi-CSI-PUCCH-ResoruceList*, UE will determine one PUCCH resource for UCI multiplexing based on the total payload of UCI. Thus, it is possible that the PUCCH resource after UCI multiplexing is different from the original CSI PUCCH resource that overlapped with HARQ-ACK. Thus, it is possible that HARQ-ACK is moved to a different sub-slot after multiplexing. To solve this issue, the following proposal was given.

**Proposal 2: For the multiplexing among overlapping channels with a given priority index, if a UE is provided *subslotLengthForPUCCH* for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing.**

# Round 1 discussion

Based on the companies’ contribution and draft CR, all companies think that it is preferable that UE does not expected that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing. However, there are different view on handing of SR multiplexed with sub-slot HARQ-ACK. The moderator brings following proposal as a baseline, and would like to suggest to discuss SR as a next step in order to check which specification changes are needed.

Proposal 1 in Round 1:

For the multiplexing among overlapping channels with same a given priority index, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing.

*Please share your view on proposal 1.*

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| Company name | Comments |
| Apple | Support Proposal 1 |
| Qualcomm | Support Proposal 1. Further, we agree with the FL’s suggestion to first settle on the HARQ-ACK only case, and then discuss SR as next steps. |
| vivo | support |
| CATT | Support in principle. We think the proposal is for multiplexing of PUCCHs only but does not apply to HARQ-ACK multiplexing on PUSCH. In addition, a minor editorial comment is that “same” in the proposal can be removed.  For the multiplexing among overlapping PUCCH channels with ~~same~~ a given priority index, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing. |
| HW/HiSi | We support the proposal. |
| Samsung | We can live with the updated proposal by CATT, although we prefer to limit the proposal to low priority. |
| OPPO | Support the proposal |
| Nokia, NSB | Support the proposal, and we are fine with CATT’s edits. |
| Ericsson | We have two questions about the proposal:   1. In our understanding, HARQ-ACK moves to a different slot only happens when multiplexing with CSI with *multi-CSI-PUCCH-ResourceList*. Are there any other cases this may happen? If not, then this condition should be spelled out “when HARQ-ACK is to multiplex with the CSI in a PUCCH and *multi-CSI-PUCCH-ResourceList* is provided” 2. Since this is conditioned on *multi-CSI-PUCCH-ResourceList*, and *multi-CSI-PUCCH-ResourceList* is only in the first *PUCCH-Config*, we agree with Samsung that this is only for low priority.   38.213 section 9.2.5.2: “If a UE is provided first and second *PUCCH-Config*, *multi-CSI-PUCCH-ResourceList* is provided by the first *PUCCH-Config*, and *PUCCH-ResourceId* in *pucch-CSI-ResourceList* or *multi-CSI-PUCCH-ResourceList* indicates a corresponding PUCCH resource in *PUCCH-Resource* provided by the first *PUCCH-Config*.”  @Moderator   1. For my background knowledge, there is no other case than multi-CSI resource since SR resource are confined with sub-slot. In the last meeting, some companies suggest to make the sentence in the HARQ-ACK point of view and it brought larger support.  In the technical aspect, this would make the conclusion robust from other decision on UL multiplexing (such as adaptation of new CSI reporting, new PUCCH resource, or intra-UE inter-priority UL multiplexing). Moreover, in Rel-16 specification, UL multiplexing is performed multiple times until getting final result. Considering that, it would be better to have generalized expression. 2. See comments in 1). Considering beneficial aspect, I would like to suggest have generalized expression unless specific use case of changing sub-slot via multiplexing. |
| ZTE | Support |
| DOCOMO | Support |

For SR handling, there are two different view in this meeting. First one is from Huawei’s contribution [1] and second one is from Nokia’s contribution [4].

From [1]:

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| * + **Issue #3-2: Whether it is allowed to multiplex SR into another sub-slot?**   The sub-slot is introduced in Rel-16 only for HARQ-ACK. Although the PUCCH resource for CSI and SR should be confined within the sub-slot if the corresponding PUCCH-config is provided with *subslotLengthForPUCCH*, such restriction is only made for convenience when multiplexing with HARQ-ACK. Thus in our view, it is allowed to multiplex SR into another sub-slot.   * + **Issue #3-3: Whether it is allowed to multiplex SPS HARQ-ACK in a sub-slot with other PUCCH transmission in different sub-slot?**   Based on our views on issue #3-1 and #3-2, it should be allowed to multiplex SPS HARQ-ACK in a sub-slot with other PUCCH transmission(s) in different sub-slot(s). For example, if the SR is multiplexed with CSI and then the PUCCH resource is changed to another sub-slot due to an increased payload size, it should be allowed to multiplex SPS HARQ-ACK in this other sub-slot with the SR from the original sub-slot. |

From [4]:

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| In RAN1#105-e, the issue related to *CSI-PUCCH-ResourceList* where SPS HARQ-ACK is multiplexed has been discussed without reaching an agreement. Also, other somewhat related sub-issues have been raised, and FL summed up all these issues as follows (see FL summary R1-2106358):   * Issue #3-1: Whether it is allowed to multiplex SPS HARQ-ACK into another sub-slot? * Issue #3-2: Whether it is allowed to multiplex SR into another sub-slot? * Issue #3-3: Whether it is allowed to multiplex SPS HARQ-ACK in a sub-slot with other PUCCH transmission in different sub-slot?   To avoid both Issue #3-2 and Issue #3-3, one possible approach would be that the gNB should guarantee there would be no inter-sub-slot multiplexing if sub-slot HARQ-ACK is involved. This would basically be a generalization of the above proposal to also cover SR (in addition to SPS HARQ-ACK) and would imply that multiplexing CSI and SR shouldn’t lead to moving to a different sub-slot. It should be noted that this issue appears only for low-priority PUCCH. |

Based on above views, I summarized as two options as following

* **Option 1: Allow to multiplex SR into another sub-slot and allow to multiplex moved SR with SPS HARQ-ACK as long as the Proposal 1 satisfies.**
  + It is allowed to multiplex SR into another sub-slot.
  + It is allowed to multiplex HARQ-ACK with other UCI scheduled in another sub-slot.
* **Option 2: Generalize the Proposal 1 to cover SR**
  + No sub-slot changing after UL multiplexing is guaranteed by gNB
  + As a result, multiplexing CSI and SR shouldn’t lead to moving to a different sub-slot

From those point of views, the moderator brings following question.

Question 1 in Round 1:

Please indicates your preference on Options above. It is highly appreciated to provide reasons in detail.

*Please share your view on above options.*

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| Company name | Comments |
| Apple | We support Option 2 |
| Qualcomm | We slightly prefer Option 1, but are fine with Option 2 if it’s the majority view.  Justification: The reason to not allowing HARQ-ACK to be moved to different slots are 1) timeline considerations, and 2) there is no procedure defined in NR to handle multiplexing of two HARQ-ACK codebooks in Rel-16. However, neither of these are of concern for SR. Therefore, Option 1 is preferred for SR since it puts less restrictions to the gNB configuration.  From UE implementation perspective, we don’t see much different between Option 1 and Option 2. |
| Vivo | Same view with Qualcomm. Option 1 is slightly preferred but option 2 can be accepted if it’s the majority view. In Rel-15, if there are only overlapped SR and CSI, SR is multiplexed on one PUCCH from multi-CSI-PUCCH-ResoruceList, there is no any restriction for sub-slot. In Rel-16, sub-slot is introduced in Rel-16 only for HARQ-ACK. Although the PUCCH resource for CSI and SR should be confined within the sub-slot if the corresponding PUCCH-config is provided with subslotLengthForPUCCH, such restriction is only made for convenience when multiplexing with HARQ-ACK. |
| CATT | We are fine with either option. |
| HW/HiSi | We prefer Option 1 but if the majority wants to go with Option 2, then this is also fine. |
| Samsung | Support Option 2.  We have strong concern on Option 1  We don’t see any strong motivation to change sub-slot after multiplexing. Also, we think there is timeline issue for Option 1.  Consider the example below, whether SR is multiplexed in CSI PUCCH #1 depends on the reception of DCI and the DCI can come after SPS HARQ-ACK PUCCH #2. Therefore, whether SPS HARQ-ACK PUCCH #2 is multiplexed with CSI PUCCH#1 depends on a DCI comes later than the SPS HARQ-ACK PUCCH #2. This case should clearly be avoided. |
| OPPO | Similar view with QC, vivo and HW, slightly prefer option 1 and fine with option 2 if it is majority view. |
| Nokia, NSB | We prefer Option 2 as, whenever a sub-slot HARQ-ACK is involved, the procedure to determine the final PUCCH resource (for multiplexing) is applied per sub-slot. We also agree with the arguments made by Samsung. |
| Ericsson | Option 1.  If there is HARQ-ACK in the multiplexing, i.e., multiplexing of {HARQ-ACK, SR, CSI}, then Proposal 1 covers SR as well.  If there is no HARQ-ACK in the multiplexing, then multiplexing of {SR, CSI} follows slot-level procedure as in Rel-15. We do not see any reason to impose additional restriction, since sub-slot was introduced in Rel-16 for HARQ-ACK. |
| ZTE | Prefer option 1 and can accept option 2 if it is majority view. |
| DOCOMO | We prefer Option1 and can live with Option 2 |

# Round 2 discussion

Based on the companies’ input so far, one suggestion and one concern has been raised in the round 1.

For the proposal 1, most of companies support the proposal and CATT’s modification. The moderator would bring CATT modifications as updated proposal 1.

Samsung and Ericsson commented that the proposal can be limited to low priority since the problematic case currently happens only with low priority. Actually we tried to limit to low priority in the RAN1#105-e email discussion, however, it hasn’t gotten companies support. Though it has no harm but also has no benefit. For the sake of the progress, the moderator change the proposal to be limited to low priority; priority index 0. If someone raises concern on that change, the change would revert for “a given priority index”. Hope it is understandable.

Proposal 1 in Round 2:

For the multiplexing among overlapping PUCCH channels with ~~a given~~ priority index 0, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of the given priority index, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is moved to a different sub-slot after multiplexing.

*Please share your view on proposal 1.*

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| Company name | Comments |
| Nokia, NSB | Support the proposal. |
| vivo | OK |
| HW/HiSi | We think that we don’t need to explicitly mention priority index 0. The rule that is here defined, should apply generally to HARQ-ACK when UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook. |
| CATT | We think Ericsson’s suggestion is reasonable which makes the proposal clearer. In addition, since “a given” is deleted “the given priority index” should be changed to “priority index 0”. Therefore, it is proposed to revise the proposal as follows.  For the multiplexing among overlapping PUCCH channels with ~~a given~~ priority index 0, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of ~~the given~~ priority index 0, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) in one sub-slot is ~~moved to~~ multiplexed in a PUCCH configured by *multi-CSI-PUCCH-ResourceList* in a different sub-slot after multiplexing. |

For the issues on SR, most of companies comments that it is possible to accept either Option 1 or option 2. One companies raised strong concern on Option 1 with an example of the corner case, another companies only prefers Option 1 in order to keep legacy behavior when sub-slot based HARQ-ACK doesn’t exist in the slot.

Regarding Samsung’s example, the exampled case is not a new case if HARQ-ACK PUCCH #2 doesn’t exist. But it is true that it becomes far more difficult to solve such case via gNB scheduling due to sub-slot structure. Moreover. Since UE cannot predict gNB scheduling, UE should consider both slot-level operation and sub-slot-level operation at the same time. Thus, it seems practically difficult to ensure 100% same UE behavior as in Rel-15 once UE is configured with sub-slot. As a moderator perspective, I would like to suggest Option 2, considering those corner cases and potential problems not identified yet. Thus, the moderator brings following proposals.

Proposal 2 in Round 2:

Update Proposal 1 to cover UL multiplexing with SR as following:

For the multiplexing among overlapping PUCCH channels with priority index 0, if a UE is provided subslotLengthForPUCCH for the HARQ-ACK codebook of priority index 0, UE does not expect that the HARQ-ACK corresponding only to SPS PDSCH(s) or SR of priority index 0 in one sub-slot is moved to a different sub-slot after multiplexing.

*Please share your view on proposal 2.*

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| Company name | Comments |
| Nokia, NSB | Support the proposal. |
| vivo | OK |
| HW/HiSi | Ok to add SR. But not ok to the whole text (PUCCH channels with priority index 0) which is imported from Proposal 1. |
| CATT | We are fine to have the same restriction for SR but suggest revising the wording as commented for proposal 1 in Round 2. |

# References

1. R1-2106488, CSI-PUCCH-ResourceList where SPS HARQ-ACK multiplexed, Huawei, HiSilicon
2. R1-2106677, Multi-CSI-PUCCH-ResourceList with Multiplexed SPS HARQ-ACK, Ericsson
3. R1-2106826, [Draft CR] Clarification on Inter-sub-slot multiplexing of low-priority UCIs, Nokia, Nokia Shanghai Bell
4. R1-2107557, Discussion on Nokia draft CRs on Rel-16 URLLC/IIoT Scheduling/HARQ and SPS enhancements, Nokia, Nokia Shanghai Bell
5. R1-2107983, Maintenance on SPS enhancements, vivo