**3GPP TSG RAN WG1 #102e R1-** **20xxxxx**

**August 17th – 28th, 2020**

**Agenda item:** 7.2.5.4

**Source:** Moderator (Qualcomm)

**Title:** Summary #3 of [102-e-NR-L1enh-URLLC-Scheduling and HARQ-02]

**Document for:** Discussion and Decision

# 1 Introduction

This document summarizes the companies’ views and captures the agreements related to the following email discussion:

[102-e-NR-L1enh-URLLC-Scheduling and HARQ-02] Processing order of intra-UE prioritization and multiplexing and handling CBG-based PUSCH retransmission – Kianoush (Qualcomm)

* Whether/how to perform multiplexing/PUCCH overriding for the LP channels in case of collision.
  + Starting point for the discussion:
    - LP multiplexing is performed similar to Rel. 15 as if HP channels do not exist; this means that LP operations, multiplexing/overriding/etc, are performed before cancellation.
    - HP multiplexing is performed independently.
    - Similar to the current spec., any HP DCI can trigger a cancellation.
* Re-transmission of the CBG-based PUSCH with cancellation
  + Option 1: the UE is not expected to be scheduled for a re-transmission of the TB including the last CBG if each of the other CBGs (except for the last one) have either not been transmitted at least once before or are not scheduled for a re-transmission in the same UL grant as the last CBG.
  + Option 1a: The UE is not expected to be scheduled for a re-transmission of a CBG #N in a given TB unless CBG #N-1 has been transmitted before or is scheduled in the same UL grant that includes CBG#N.
  + Option 2: the TB CRC for the retransmission of the same TB is set to all zeros.
  + Option 3: It is up to UE implementation to determine which values to use as the TB CRC (which may not be the actual TB CRC) for the retransmission of the same TB.
  + Option 4: the minimum processing time for PUSCH scheduled for re-transmission is extended by D symbols.
  + Option 5: The UE is not expected to be scheduled with partial TB for the retransmission.
* Discussions/Agreements by 8/21, TPs by 8/28

A summary of the companies’ proposals is captured in [1]. **Companies are encouraged to share their views by Wednesday August 19th.**

# 2 Issue#1: Whether/how to perform multiplexing/PUCCH overriding for the LP channels in case of collision

**Alternative #1:** According to the current specification and the discussion from the last meeting, once a UE detects a HP DCI scheduling a HP channel overlapping with a LP channel, the transmission of the LP channel (including its content) is dropped.

An example is given in the figure below:



Once the UE detects HP DCI1, LP PUCCH including its contents is dropped. Hence, the PUCCH cannot be overridden by another DCI, i.e., LP DCI2, later. In other words, after receiving the HP DCI1, the LP multiplexing/PUCCH overriding operations should be assumed to be reset by the gNB and the UE. There is no ambiguity on either side.

**Alternative #2:** As discussed during the last meeting, the operation can be optimized by requesting the UE to follow the multiplexing/overriding procedures for the LP channels before applying the cancellation. In other words, multiplexing and overriding of the LP channels are not impacted by cancellation; cancellation is applied at the last stage.

Considering the example above, a UE follows the LP PUCCH overriding and then transmits all HARQ-ACKs piggybacked on the LP PUCCH scheduled by LP DCI2. For the case of PUCCH overriding, there is no ambiguity between the UE and the gNB even if the UE applies cancellation during the intermediate steps (There really is no cancellation over the air; the UE only decides not to transmit on some resources, while keeping the content for the future transmissions.)

Now, consider a scenario where a LP PUSCH is in the overlapping group. One example is shown below:



In this case, LP PUCCH gets multiplexed with the LP PUSCH. However, there could be an ambiguity at the gNB; basically, depending on when the UE decides not to transmit the LP PUSCH, the outcome could be different. If the UE decides not to transmit earlier (i.e., before decoding HP DCI2), the final LP channel will not be transmitted. If it decides later, the UE may multiplex HP PUCCH into HP PUSCH and then also transmits the LP PUSCH. Note that the ambiguity is only 1-bit, i.e., the final LP channel does not change; it is where the gNB expects it to be. However, whether a UE transmits on that resource or not depends on when the UE decides to perform cancellation.

**Question #1: In the table below, please state if you prefer Alternative #1 (current specification) or Alternative #2 above? If you prefer Alternative #1, is there a need to further clarify the procedure in the spec? If you prefer Alternative #2, do you agree that a UE should follow the steps mentioned below?**

* **LP multiplexing is performed similar to Rel. 15 as if HP channels do not exist; this means that LP operations, multiplexing/overriding/etc, are performed before cancellation.**
* **HP multiplexing is performed independently.**
* **Similar to the current spec., any HP DCI can trigger a cancellation.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Alternative** | **Comments** |
| vivo | Alternative #2 | Agree the steps FL summarized for Alternative #2. |
| HW/HiSi | Alternative #2 | We do not regard Alternative #2 just as an optimization.  In our view, the PUCCH and the UCI should be decoupled. This is similar to PUCCH overriding, the PUCCH is overridden, i.e. the resources where it should have been transmitted are cancelled, and the UCI can be included in a new channel. In Rel-15 we have already a situation when a PUCCH is canceled due to colliding SSB symbols but the UCI is preserved and can be sent in another PUCCH.  We agree on steps 2 and 3 from the FL for Alternative #2. For the first step, we would like to comment. In our view, we should not say that “**LP operations, multiplexing/overriding/etc, are performed before cancellation**” , but instead we should say that UCI operations are performed decoupled from PUCCH cancellation operations. For example, a first LP PUCCH is cancelled when colliding with a HP PUCCH, there is no way to recover. But the UCI should follow the Rel-15 behavior and could be included in another PUCCH if the Rel-15 multiplexing conditions are met.  For Alternative #1, we have a question for our understanding. According to the FL description, the LP/PUCCH overriding procedures should be assumed to be reset. I am wondering, if this is a new behavior that would need to be captured in the spec? |
| OPPO | Alternative#1 | Principle of Alternative #1, e.g. immediate multiplexing/dropping has been agreed last meeting. The benefit of Alternative #1 is low complexity for UE implementation and gNB scheduling.  The remaining issue of agreement last meeting is whether UCI is dropped or not when PUCCH is cancelled.  Option 1: UCI is dropped   * Low complexity for UE implementation   Option 2: UCI can be multiplexed in later LP PUCCH according to Rel-15 multiplexing procedure.   * Enhancement on UE implementation may be required, e.g. different timeline/process to deal with PUCCH transmission/UCI storage.   For any option, it is necessary to clarify UCI processing when PUCCH is dropped.  Alternative #1 looks like Option 1. We prefer Alternative #1 and also could compromise to Alternative#1 with modification (Option 2) |
| LG | Alternative #2 | Agree FL’s view on alternative #2.  Based on current specification, UE cannot determine actual PUCCH transmission until T\_proc,2 before earliest starting symbol among overlapping PUCCH(s) and PUSCH. Thus, there is almost no ambiguity between UE and gNB. In this case, Alternative #2 is more reasonable. |
| MediaTek | Alternative #1 | We don’t see a need to further clarify the procedure in the spec. |
| Qualcomm | Alternative #2 | The procedures for LP channels should be performed independently.  @HW: Restarting the procedures in case of Alternative #1 is due to the fact that the LP channels including their contents are dropped. So, the dropped content cannot be multiplexed into another channel. This is not a new behavior; in fact, it was the intention of Alternative #1. But, if Alternative #1 is agreed, then, some clarification in the specification might be needed.  @OPPO: For Alternative #1, there is no ambiguity in what happens to the UCI; when a LP channel is cancelled, its content is also assumed to be cancelled. As a FL, I am still not sure which Alternative you prefer; from the discussions during the last meeting, it seemed that your preference is Alternative #2.  [OPPO] Yes, we agree with you that Alternative #1 is clear. We want to express the ambiguity in agreement last meeting. Sorry to make you confusion.  Among alternative #1 and alternative #2 , we prefer to alternative #1 due to it is more in line with agreement last meeting. In our understanding, intention of agreement last meeting is to cancel low priority channel immediately and no recover, which is benefit for UE implementation and gNB scheduling.  Alternative #2 violates agreement last meeting due to cancellation is not done immediately. In other words, cancelled LP PUCCH may recover due to later DCI scheduling. To be specific, in your case, LP PUSCH will recover due to HP DCI 2. So we cannot accept alternative #2.  Last meeting, our confusion is whether UCI in cancelled PUCCH can be multiplexed in later PUCCH according to Rel-15 procedure. Both solutions are acceptable but not clear for us, maybe slightly prefer option 2 in our comment due to no spec impact. After checking with implementation, option 1 is easier. And clarification for option 2 in spec is also required. So we prefer option 1 now. And we could compromise to option 2 for progress. |
| Samsung | Alternative #2 | Current specification already includes alternative #2 in case of PUCCH for HARQ-ACK feedback. “The PUCCH resource determination is based on a PUCCH resource indicator field [5, TS 38.212], if present, in a last DCI format, among the DCI formats that have a value of a PDSCH-to-HARQ\_feedback timing indicator field”. So, although some of intermediate LP PUCCH resources are cancelled, we think that UCI (HARQ-ACK) information is still valid to multiplex in other PUCCH resource indicated by later DCI format. |
| DOCOMO | Alternative #2 | Agree the steps FL summarized for Alternative #2. |
| Ericsson | Modified Alt 2 (Please see explanations) | Thanks for the efforts by FL to address the issue.  From our perspective, what is important is lack of ambiguity between UE and gNB because it causes gNB unnecessary blind detection.  The issue is that it is not clear when to apply the agreement from the last meeting. Please note that the spec states to resolve first overlapping between same priority (high/low).  There are 4 operations:   * **LP overlapping resolution (multiplexing)** * **HP overlapping resolution (multiplexing)** * **Prioritization between overlapping LP and HP** * **Any HP DCI can trigger a cancellation.**   The first 3 above, were the behavior according to spec which results in no ambiguity. The last agreement resulted in the last operation which is not clear when it is applied. This is the source of ambiguity.  I am wondering since only LP transmissions are affected, could we have the following steps where we apply the last agreement on the resources before resolving overlapping between LP or HP:  Modified Alternative:   * **Trigger cancellation of LP PUCCH/PUSCH resource by HP DCI**   + **The LP PUCCH/PUSCH resources may be overlapping** * **LP overlapping resolution (multiplexing)** * **HP overlapping resolution (multiplexing)** * **Prioritization between overlapping LP and HP**   Which means the text in the spec for the last agreement, should come before the text for overlapping resolution between same priority.  I think in this case, the UE doesn’t have to do unnecessary multiplexing. Also, based on this rule, the gNB would also avoid scheduling of LP PUSCH as shown in the figure. Because, based on modified Alt, the outcome would be as the following:   * First, LP PUSCH is csnceleld by HP PUCCH. * LP PUCCH would be transmitted * HP PUSCH mux with HP UCI would be transmitted.   In fact, based on this rule, it is stupid of gNB to schedule LP PUSCH after HP DCI1, even. |
| Intel | Alternative #2 | Agree that the PUCCH or PUSCH resources for transmissions are determined based on over-riding/multiplexing rules in Sections 9.2.5 and 9.2.6, but the UCI is not dropped if an intermediate LP resource is overlapping with a HP resource. However, we do not think any spec change is necessary as the relevant parts of the specs refers to “PUCCH or PUSCH transmissions” in the context of prioritization, and thus, includes the independent handling of LP and HP overriding/multiplexing already. |
| ZTE | Alternative #1 | We prefer Alternative #1, which is consistent with the current specifications. In order to make the specification more clear, in cases involving cancellation issues, it should be clarified: *due to the conflict between the low-priority channel and the high-priority channel, once the UE receives the DCI (if any) corresponding to the high-priority channel, Low priority channels should be cancelled immediately.*  If the above clarification is missing, there are some misunderstandings. Two possible consequences are expected from the below figure.  The first consequence is that after each high-priority DCI is received, the corresponding conflict is handled immediately.  The second consequence is that after the UE receives the high-priority DCI1, it waits until the high-priority DCI2 is received and then handles the conflict.  For us, the first consequence is better.  We believe that following the DCI receiving order and not waiting for any final DCI is the clear way to deal with conflicts without any ambiguity.    In addition, we support the decoupling between HARQ-ACK and PUCCH, we believe that for PUCCH with HARQ-ACK, the R15 mechanism can be reused. For example, if the HARQ-ACK of the subsequent PDSCH is indicated by the corresponding DCI to be in the same slot as the HARQ-ACK of the previous PDSCH, the corresponding HARQ-ACK PUCCH is determined according to the later DCI.  For other SR/CSI PUCCH, PUCCH and corresponding SR/CSI should be discarded together. |
| CATT | Alternative #2 | We agree with Huawei that UCI and PUCCH should be decoupled.  In case a first intermediate LP PUCCH1 is cancelled due to overlapping with a HP channel, the UCI can still be transmitted on a final PUCCH2 as shown below.    Note that the figure under Alternative #1 involves out-of-order HARQ between PUCCHs scheduled by HP DCI1 and LP DCI2.  For the case illustrated in the figure under Alternative #2, the LP UCI is multiplexed in the LP PUSCH and then cancelled by HP PUCCH although the HP PUCCH is not transmitted since the HP UCI is transmitted in the HP PUSCH. |
| Nokia, NSB | Alternative #2 | As majority of other companies.  We agree with the E/// comment above, that some clarification on the “*Any HP DCI can trigger a cancellation*” is needed. |
| Apple | Alternative #1 | Our understanding of the agreement is alternative #1. Basically the channel (including the contents) can be dropped right away. |

**Proposed agreement: For handling intra-UE prioritization across channels of different priorities and multiplexing across the channels of the same priority, a UE performs the following procedures:**

1. **LP multiplexing is performed similar to Rel. 15 as if HP channels do not exist; this means that LP operations, multiplexing/overriding/etc, are performed before cancellation.**
2. **HP multiplexing is performed independently.**
3. **Similar to the current spec., any HP DCI can trigger a cancellation; however, only the final LP channel after mux/overriding may get cancelled by a UE.**

Based on the comments, it seems there is a concensus on the first two items above. The remaining part is item 3, i.e., how the transmission of the LP and HP channels should interact.

Consider the following two examples:





When does the UE decide whether a final LP PUCCH or PUSCH should be dropped?

* **Alt1:** It is up to the UE to decide whether the transmission of the final LP channel (after performing multiplexing/overriding) should be cancelled after detecting any DCI scheduling an overlapping HP transmission.
* **Alt2:** A UE cancels the transmission of the final LP channel (after performing multiplexing/overriding) if any DCI schedules an overlapping HP transmission.

# 2 Issue#2: Retransmission of the CBG-Based PUSCH with Cancellation

To handle the UE processing timeline in case the initial transmission of a CBG-based PUSCH is cancelled, the following options were considered and discussed during RAN1 #101e:

* Re-transmission of the CBG-based PUSCH with cancellation
  + Option 1: the UE is not expected to be scheduled for a re-transmission of the TB including the last CBG if each of the other CBGs (except for the last one) have either not been transmitted at least once before or are not scheduled for a re-transmission in the same UL grant as the last CBG.
  + Option 1a: The UE is not expected to be scheduled for a re-transmission of a CBG #N in a given TB unless CBG #N-1 has been transmitted before or is scheduled in the same UL grant that includes CBG#N.
  + Option 2: the TB CRC for the retransmission of the same TB is set to all zeros.
  + Option 3: It is up to UE implementation to determine which values to use as the TB CRC (which may not be the actual TB CRC) for the retransmission of the same TB.
  + **Updated Option 3: It is up to UE implementation to determine which values to use as the TB CRC (which may not be the actual TB CRC) for the retransmission of a TB whose initial transmission was cancelled.**
  + Option 4: the minimum processing time for PUSCH scheduled for re-transmission is extended by D symbols.
  + Option 5: The UE is not expected to be scheduled with partial TB for the retransmission.

As discussed, Option 1a is aligned with a reasonable gNB’s operation.

In the table below, please state whether you would agree to adopt Option 1a. If not, please provide your reasoning.

|  |  |  |
| --- | --- | --- |
| **Company** | **Option 1a (Yes/No)** | **Reasons** |
| vivo | No | As FL mentioned, a reasonable gNB’s operation is that the gNB will re-schedule the failed CBG in sequence. So if gNB schedules CBG out of sequence, it is up to UE implementation to determine which values to use as the TB CRC CBG re-transmission. Therefore, we still prefer option 3 without any spec impacts. |
| HW/HiSi | Yes | We agree that a reasonable gNB operation is to re-schedule the failed/cancelled CBGs in sequence; this is what Option 1a is trying to achieve. Because in the UE implementation we also need to consider the possibility of “unreasonable scheduling”, it would be good to spell it out in the specification. |
| OPPO | No | Agree with vivo’s comments. |
| LG | Yes | Though we don’t have strong opinion on this issue, we also think a reasonable gNB’s operation is to schedule failed CBG in sequence. If gNB schedules CBG transmission in sequence, UE would choose TB CRC its own way so it would be impossible for gNB to decode PUSCH transmission. if it is an issue, we should specify it as an error case rather than leaving it to UE implementation. |
| MediaTek | Yes | Option 1a is the expected gNB’s operation, and it will help in addressing the UE implementation issue.  Regarding vivo’s comments (i.e. adopting Option-3), it is not clear to us why we should adopt an option that is not aligned with expected gNB’s operation, and not providing extra benefit for UE implementation compared to Option-1a.  We don’t see any technical justifications for objecting to Option-1a. |
| Qualcomm | Yes | Option 1-a is aligned with a reasonable gNB’s implementation, and does not limit its scheduling flexibility. |
| Samsung | No | We still prefer option 3 – can accept option 5. The overall issue is trivial and does not require specifications. |
| DOCOMO | Yes | Option 1-a resolves the UE complexity issue with slight gNB’s scheduling restriction. |
| Ericsson |  | Our first preference is Option 1 as less restrictive. But we could be fine to Option 1a as a compromise. |
| Intel | No | Although our original preference was Option 4, thanks to the further discussions, we now understand the logic/motivations behind Option 1a better and agree that it can work as well. Thus, given more spec impact for Option 4, we are fine with dropping Option 4.  Next, between Options 1a and 3. Gven that we would be effectively relying on Option 3 for Rel-15 (as discussed last meeting, the issue exists for Rel-15 as well) and is now understood as the most reasonable gNB implementation, we would prefer to go with Option 3. |
| ZTE | No | Agree with vivo’s comments. |
| CATT | Yes | We share the same view as Ericsson. |
| Nokia, NSB | Yes | Share the same view as Ericsson & CATT. Would have preferred Option 1 but could be fine with Option 1a as a compromise. |
| Apple | Yes | It is really unclear to us how we can claim Option 3 has no specification impact. We would need to define the conditions when the UE can autonomously set the TB CRC randomly, and under these conditions, the gNB would not check TB CRC. Otherwise Option 3 would not work. |

# 3 References

**[1] R1-2007033, “*Summary of the remaining issues on HARQ and scheduling enhancements for URLLC: preparation phase*,” Moderator (Qualcomm)**