**3GPP TSG-RAN WG1 Meeting #110R1-220xxxx**

**Toulouse, France, August 22nd – 26th, 2022**

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

**Source: Moderator (Apple)**

**Title: Summary of discussions on UCI multiplexing and prioritization in Rel-16 URLLC**

**Document for: Discussion and Decision**

# 1 Introduction

This contribution provides the summary of discussions on UCI multiplexing and prioritization in Rel-16 URLLC.

Section 2 provides the background information, including a summary of contributions submitted to RAN1#110. Section 3 captures the discussions. Section 4 summarizes the outcome.

# 2 Background

For UE procedures for UCI multiplexing and prioritization, a working assumption was agreed in RAN1#102-e:

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| --- |
| **Working assumption**   * Multiplexing/overriding/etc. 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. * A UE cancels the transmission of a LP channel including any intermediate scheduled LP transmission that does not overlap with any LP channel, if any DCI schedules an overlapping HP transmission with the LP channel, before performing multiplexing/overriding HP channels if any. * Multiplexing/overriding of HP channels is performed as if LP channels do not exist. * A final HP channel is prioritized if it overlaps with a final LP channel, after performing multiplexing of HP channels |

This was later captured in TS 38.213 as follow:

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| --- |
| **TS38.213**  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports before considering limitations for UE transmission as described in clause 11.1 and clause 11.1.1, including repetitions if any, the UE first resolves the overlapping for PUCCH and/or PUSCH transmissions of smaller priority index as described in clauses 9.2.5 and 9.2.6. Then,  - if a transmission of a first PUCCH of larger priority index scheduled by a DCI format in a PDCCH reception would overlap in time with a repetition of a transmission of a second PUSCH or a second PUCCH of smaller priority index, the UE cancels the repetition of a transmission of the second PUSCH or the second PUCCH before the first symbol that would overlap with the first PUCCH transmission  - if a transmission of a first PUSCH of larger priority index scheduled by a DCI format in a PDCCH reception would overlap in time with a repetition of the transmission of a second PUCCH of smaller priority index, the UE cancels the repetition of the transmission of the second PUCCH before the first symbol that would overlap with the first PUSCH transmission  where  - the overlapping is applicable before or after resolving overlapping among channels of larger priority index, if any, as described in clauses 9.2.5 and 9.2.6  - any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in clause 11.1 and clause 11.1.1  - the UE expects that the transmission of the first PUCCH or the first PUSCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception  - is the PUSCH preparation time for a corresponding UE processing capability assuming [6, TS 38.214], based on and as subsequently defined in this clause, and is determined by a reported UE capability |

There was a conclusion agreed in RAN1#103-e to clarify “before or after” in 213:

**Conclusion**

In the following clause from Section 9 of TS 38.213:

“where

* The overlapping is applicable before or after resolving overlapping among channels of larger priority index, if any, as described in Clause 9.2.5”

the meaning of “before or after” should be interpreted as follows: A UE checks the overlap between a HP channel and a low priority channel before multiplexing. If there is an overlap, the LP channel gets cancelled. If not, a UE performs multiplexing across the HP channels. If then there is an overlap with a LP channel, the LP channel gets cancelled.

In addition, we had the following agreement:

**Agreement**: (RAN1#101-e)

* If a UE is expected to cancel a scheduled low priority PUCCH/PUSCH due to a first DCI scheduling an overlapping high priority channel, the UE is not expected to transmit the scheduled low priority PUCCH/PUSCH due to a second DCI scheduling PUCCH/PUSCH that is received after the first DCI.
  + Note: The collision between HP PUSCH and LP PUSCH is not covered by this agreement.

The discussion has continued since then on clarification for the exact procedures. The most recent email discussions are captured in [1]-[4], and the options that had been discussed include the following:

* **Option 2 (v2)**: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.
  + Any HP channel with a corresponding DCI that overrides or overlaps with a HP channel that overlaps with a LP channel shall meet the cancellation timeline, namely all ~~HP~~ DCIs corresponding to these HP channels must arrive *Tproc,2+d1*before the **earliest** symbol ~~of the LP channel that would be cancelled by the any~~ of these HP channels.
  + All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channel
* **Option 2’ (updated)**: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels. (from Samsung)
  + Any HP PUCCH channel that overrides or overlaps with a HP PUCCH channel that overlaps with a LP channel shall meet the cancellation timeline, namely all HP DCIs must arrive Tproc,2+d1 before the earliest symbol that would be cancelled by the final HP PUCCH channel.
  + If a UE detects a first DCI format indicating a first resource for a PUCCH transmission with corresponding HARQ-ACK information in a slot and also detects at a later time a second DCI format indicating a second resource for a PUCCH transmission with corresponding HARQ-ACK information in the slot, UE does not expect the second resource starts earlier than the start of the first resource.
  + All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels.
* **Option 3**: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:
  + the UE checks overlapping between HP and LP channel for each HP grant it receives, including any intermediate HP channel that results from UCI multiplexing and PUCCH overriding triggered by each of the HP grant.
* **Option 3a**: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:
  + A UE checks the overlap between a HP channel and a low priority channel before multiplexing. If there is an overlap, the LP channel gets cancelled. If not, a UE performs multiplexing across the HP PUCCH channels. If then there is an overlap with a LP channel, the LP channel gets cancelled. Then, multiplexing between PUCCH and PUSCH is performed. If then there is an overlap with a LP channel, the LP channel gets cancelled
* **Option 3b**:
  + Cancellation timeline needs to be satisfied for a group of overlapping HP channels as long as one of the HP channels overlaps with a LP channel.
  + HP PUCCH for HARQ-ACK indicated by each DCI can cancel LP.
  + Final HP PUCCH or PUSCH is used to cancel LP.
* **Option 4**: whether the intermediate HP channels is used to cancel the LP channels is left to UE implementation.
* **Option 5**: The UE makes a determination about canceling the LP channel at the cancellation deadline. This determination is based on the multiplexing/overriding of the HP channels that are determined up to the cancellation deadline.
  + Multiplexing/overriding of the HP channels are performed based on their associated timelines defined in R15.
  + Each and every dynamically scheduled HP channel as well as the HP channels that are the result of the HP channel multiplexing/overriding and are overlapping with a LP channel should satisfy the cancellation timeline, i.e., the gap between the ending symbol of the HP DCI to the starting symbol of that HP channel should be at least *Tproc,2+d1.*
  + The UE cancels the LP channel starting from the first symbol that overlaps with the HP channel at the latest, i.e., the current specification wording is kept.
  + Once a LP channel is determined to be cancelled at the cancellation deadline, a UE is not expected to revert its decision.

This issue is discussed in 6 contributions submitted to RAN1#109-e [5]-[10], mainly focusing on Option 2 and Option 3. Companies’ views are summarized as follows:

* Option 2: Huawei/HiSi, OPPO, Apple
  + Apple provided a TP for Option 2, which is essentially the same as the TP discussed in [4].
* Option 3: ZTE
  + ZTE provided a TP to add the reference to Clause 9.2.3.
  + Nokia proposed a CR to add the following sentence in the spec if Option 3 is agreed.
    - “If a UE detects a first DCI format scheduling a PUCCH or PUSCH transmission of larger priority index that would overlap with a PUCCH or PUSCH transmission of smaller priority index, the UE does not expect to transmit the PUCCHs or PUSCHs of the smaller priority index due to a detection of a second DCI format after the detection of the first DCI format.”
* Option 2 and 3 as UE capability: Huawei/HiSi, OPPO
* Option 1: Huawei/HiSi
  + Option 1: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels
    - The UE is not expected a later DCI in a PDCCH reception overrides cancellation of a repetition of PUCCH/PUSCH transmissions of smaller priority index due to overlapping with a PUCCH/PUSCH transmission of larger priority index scheduled by an earlier DCI format in a PDCCH reception
    - All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels.

There has been a long time debate on whether Rel-15 would require a UE to perform multiplexing after receiving each DCI already. Huawei/HiSi and OPPO provided more explanations on why they do not agree this is the case.

# 3 Discussions

# 4 Outcome

# References

1. R1- 2108655, Summary of [106-e-NR-L1enh-URLLC-06] Issue #10: UE Procedures for UCI Multiplexing and Prioritization, Moderator (Qualcomm), RAN1#106-e, Aug. 2021.
2. R1-2112889, Summary of email discussion [107-e-NR-L1enh-URLLC-05] on UCI multiplexing and prioritization in Rel-16, Moderator (Apple), RAN1#107-e, Nov. 2021.
3. R1-2202916, Summary of email discussion [108-e-R16-URLLC-01] on UCI multiplexing and prioritization in Rel-16, Moderator (Apple), RAN1#108-e, Feb.-Mar. 2021.
4. R1-2205606, Final summary of email discussion [109-e-R16-URLLC-01] on UCI multiplexing and prioritization in Rel-16, Moderator (Apple), RAN1#109-e, May 2022.
5. R1-2205759 Remaining issues on UCI multiplexing and prioritization Huawei, HiSilicon
6. R1-2205970 Discussion on UCI multiplexing and prioritization ZTE
7. R1-2206145 Discussion on Rel-16 UE procedure for intra-UE prioritization/multiplexing Nokia, Nokia Shanghai Bell
8. R1-2206146 [Draft CR] Intra-UE prioritization clarification for PUCCH / PUSCH scheduled by a DCI Nokia, Nokia Shanghai Bell
9. R1-2206306 Discussion on scheduling and HARQ enhancement OPPO
10. R1-2207307 Remaining issues on intra-UE multiplexing/prioritization for eURLLC Apple