**3GPP TSG RAN WG1 #105e R1-** **210xxxx**

**May 10th – 27th, 2021**

**Agenda item:** 7.2.5

**Source:** Moderator (Qualcomm)

**Title:** Summary of the Preparation Phase: Remaining Issues on HARQ and Scheduling Enhancements for URLLC

**Document for:** Discussion and Decision

# 1 Introduction

In this document, proposals and remaining issues related to URLLC HARQ and scheduling are summarized. The list of the proposals is as follows:

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| **Topic** | **Companies supporting the discussion in RAN1 #104e** | **FL Comment** |
| **Issue #1:** UE procedure for prioritization | Ericsson [1], OPPO [3], Apple [4] | Please refer to the FL comments in Section 2. From FL’s point of view, the specification is clear; it does not introduce **multiplexing of HP channels** in every intermediate steps. If RAN1 prefers it to have this also as a conclusion to conclude this discussion, it should be fine. |
| **Issue #2:** Handling of collision between DL/SSB symbols and configured HP PUCCH and PUSCH | Nokia/NSB [2], DCM [5] | Discuss during the meeting |

# 2 Issue #1

In [1], it is argued that the following step from the intra-UE prioritization makes the UE implementation complicated:

**“***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.”*

To address the case, the following TP is presented:

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| ============== START of Text Proposal 1 for TS38.213 ==========================  9 UE procedure for reporting control information  \*\*\*Unchanged text is omitted\*\*\*  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports, including repetitions if any, the UE first resolves the overlapping for PUCCH and/or PUSCH transmissions of ~~smaller~~ a same 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~~ corresponding to 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~~ corresponding to 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~~  -    the UE is not expected a later DCI in a PDCCH reception overrides cancellation of a repetition of a 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  - any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in Clause 11.1  - 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  \*\*\*Unchanged text is omitted\*\*\*  ============== END of Text Proposal1 for TS38.213 ========================== |

In [3], it is mentioned that the intermediate checking of collisions leads to a different behavior in terms of multiplexing as compared to Rel. 15. Based on the arguments in the paper, the following proposals are made:

***Proposal 1: Intermediate multiplexing should be removed from intra UE prioritization.***

***Proposal 2: The following intra UE prioritization procedure can be supported:***

* ***Overlapping resolution by multiplexing low priority PUCCH/PUSCH***
* ***Overlapping resolution by multiplexing high priority PUCCH/PUSCH***
* ***Prioritization/cancellation HP over LP***
* ***Add error case: It is not expected a later DCI in a PDCCH reception overrides cancellation of a repetition of a 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***

In [4], the same case is pointed out, and the following three solutions are proposed:

* **Option 1**: clarify that the UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels based on the current specifications.
* **Option 2**: define an error case that the UE does not expect the gNB to change the overlapping between HP and LP channels over time. With the error case being defined, the multiplexing of LP and HP channels can be separately conducted, and only the final HP channels are used to cancel LP channels.
  + The TP from Ericsson in RAN1#104b-e was the following: “the UE is not expected a later DCI in a
* **Option 3**: modify the cancellation timeline to include any HP channel that overrides or overlaps with a HP channel that overlaps with a LP channel.

**Notes for discussion from the feature lead:**

In the current specification, we have:

**“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”**

Based on the discussions in the previous meetings, this means that the UE should check the overlapping between the intermediate HP channels and the LP channels (which could themselves be the final channel for transmission or intermediate channels.) In other words, as the HP DCIs are received, the UE should check whether the HP channels should be multiplexed or not; if the do, it should check the overlapping between the resulting HP channel and the low priority channels. This is illustrated with an example in the figure below:



Let us first assume that the LP channel is scheduled; the UE first receives HP DCI #1 and checks that there is no overlap between the HP PUCCH #1 and the LP channel. Then, the UE receives the HP DCI #2 scheduling HP PUCCH #2. If PUCCH #1 and #2 are multiplexed, then the intermediate HP PUCCH is overlapping with a LP channel. Since the UE is given enough time gap between the HP DCI #2 and the intermediate HP PUCCH, the UE can initiate the cancellation of the LP channel.

Now, let us assume that the UE does not check the intermediate channels. In this case, the UE does not know whether the gNB is planning to transmit more DCIs and schedule more HP transmissions or not. As shown in the figure, if the UE waits, but no DCI is received, e.g., the HP DCI #3 is not sent by the gNB or missed by the UE, then the effective cancellation time is smaller than what is required to be.

The benefit of checking the intermediate HP channels on reducing the UE complexity, by ensuring sufficient processing time, is explained above. On the other hand, in [1], [3]-[4], it is argued that the intermediate checking steps make the UE implementation complicated.

For RAN1 #105e, the recommendation from the feature lead is as follows:

1. Discuss whether the intermediate checks are complicating the UE complexity.
2. Discuss how the proposed solutions could remove the intermediate checks, while still ensuring a guaranteed amount of time for cancellation (i.e., not requiring a UE to wait for initiating cancellation).

# 3 Issue #2

In [2], it is mentioned that the following agreement should be applicable to all remaining transmissions regardless of whether they are dynamically scheduled or not:

**Agreement**

To address collision with semi-static DL symbols and SSB, the following easy way is suggested:

* Step1: Perform intra UE prioritization (including multiplexing, overriding) according to related working assumption in 102 e-meeting and produce final PUCCHs/PUSCHs.

Step 2: Final PUCCHs/PUSCHs is cancelled by semi-static DL symbols and SSB symbols.

However, in the current specification, only the scenarios where the high-priority channel(s) is dynamically scheduled by PDCCH are considered. To address this issue, the following TP is proposed:

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| -------------------------------------------------- Start of text proposal ------------------------------------------------------  9 UE procedure for reporting control information  \*\*\* Unchanged text is omitted \*\*\*  If a UE would transmit the following channels before considering limitations for UE transmission as described in clause 11.1, including repetitions if any, that would overlap in time  - a first PUCCH of larger priority index with SR and a second PUCCH or PUSCH of smaller priority index, or  - a configured grant PUSCH of larger priority index and a PUCCH of smaller priority index, or  - a first PUCCH of larger priority index with HARQ-ACK information only in response to a PDSCH reception without a corresponding PDCCH and a second PUCCH of smaller priority index with SR and/or CSI, or a configured grant PUSCH with smaller priority index, or a PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH, or  - a PUSCH of larger priority index with SP-CSI reports(s) without a corresponding PDCCH and a PUCCH of smaller priority index with SR, or CSI, or HARQ-ACK information only in response to a PDSCH reception without a corresponding PDCCH, or  - a configured grant PUSCH of larger priority index and a configured PUSCH of lower priority index on a same serving cell  the UE is expected to cancel a repetition of the PUCCH/PUSCH transmissions of smaller priority index before the first symbol overlapping with the PUCCH/PUSCH transmission of larger priority index if the repetition of the PUCCH/PUSCH transmissions of smaller priority index overlaps in time with the PUCCH/PUSCH transmissions of larger priority index. Any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in Clause 11.1.  \*\*\* Unchanged text is omitted \*\*\*  ----------------------------------------------------- End of text proposal ------------------------------------------------------ |

In [5], the following clause is presented:

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| When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports, 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 |

It is mentioned that With the current formulation, especially from the highlighted part, the processing order of intra-UE prioritization/multiplexing and semi-static DL symbols/SSB symbols is determined only for the case where UL channel overlaps with other UL channels of different priority and semi-static DL symbols/SSB symbols. However, the ambiguity issue of the processing order is present also for the case where UL channel overlaps with other UL channels of the same priority and semi-static DL symbols/SSB symbols. To address the issue, the following changes are proposed:

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| ---------------------------------Start of Text Proposal on TS 38.213 v16.5.0-----------------------  9 UE procedure for reporting control information  <Unchanged parts are omitted>  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports, 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  - 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  <Unchanged parts are omitted>  --------------------------------------End of Text Proposal on TS 38.213 v16.4.0------------------  ---------------------------------Start of Text Proposal on TS 38.213 v16.4.0-----------------------  11.1 Slot configuration  <Unchanged parts are omitted>  For a set of symbols of a slot that are indicated to a UE as downlink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, the UE does not transmit PUSCH, PUCCH, determined from Caluses 9 and 9.2.5, PRACH, or SRS when the PUSCH, PUCCH, PRACH, or SRS overlaps, even partially, with the set of symbols of the slot.  For a set of symbols of a slot that are indicated to a UE as flexible by *tdd-UL-DL-ConfigurationCommon*, and *tdd-UL-DL-ConfigurationDedicated* if provided, the UE does not expect to receive both dedicated higher layer parameters configuring transmission from the UE in the set of symbols of the slot and dedicated higher layer parameters configuring reception by the UE in the set of symbols of the slot.  For operation on a single carrier in unpaired spectrum, for a set of symbols of a slot indicated to a UE by *ssb-PositionsInBurst* in *SIB1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon*, for reception of SS/PBCH blocks, the UE does not transmit PUSCH, PUCCH, determined from Clauses 9 and 9.2.5, PRACH in the slot if a transmission would overlap with any symbol from the set of symbols and the UE does not transmit SRS in the set of symbols of the slot. The UE does not expect the set of symbols of the slot to be indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, when provided to the UE.  If a UE  - is configured with multiple serving cells and is provided *half-duplex-behavior* = 'enable', and  - is not capable of simultaneous transmission and reception on any of the multiple serving cells, and  - indicates support of capability for half-duplex operation in CA with unpaired spectrum, and  - is not configured to monitor PDCCH for detection of DCI format 2\_0 on any of the multiple serving cells,  for a set of symbols of a slot that are indicated to the UE for reception of SS/PBCH blocks in any of multiple serving cells by *ssb-PositionsInBurst* in *SystemInformationBlockType1* or by *ssb-PositionsInBurst* in *ServingCellConfigCommon*, when provided to the UE, the UE does not transmit PUSCH, PUCCH, determined from Clauses 9 and 9.2.5, or PRACH in the slot if a transmission would overlap with any symbol from the set of symbols, and the UE does not transmit SRS in the set of symbols of the slot in any of multiple serving cells.  <Unchanged parts are omitted>  --------------------------------------End of Text Proposal on TS 38.213 v16.5.0------------------ |

# 9 References

**[1] R1-2104216, “Maintenance of scheduling and HARQ for Rel-16 NR URLLC,” Ericsson**

**[2] R1-2104312, “Rel-16 URLLC/IIoT maintenance of PDCCH, scheduling/HARQ and SPS enhancements,” Nokia, Nokia Shanghai Bell**

**[3] R1-2104800, “Remaining issues on scheduling and HARQ,” OPPO**

**[4] R1-2105084, “Remaining issues on intra-UE multiplexing/prioritization for eURLLC,” Apple**

**[5] R1-2105682, “Corrections on scheduling/HARQ for Rel-16 URLLC,” NTT DOCOMO Inc.**