**3GPP TSG RAN WG1 #104bis-e R1-** **21xxxxx**

**April 12th – 20th, 2021**

**Agenda item:** 7.2.5

**Source:** Moderator (vivo)

**Title:** Summary of the Remaining Issues on intra-UE prioritization/multiplexing and eCG

**Document for:** Discussion and Decision

# 1 Introduction

In this document, proposals and remaining issues related to intra-UE prioritization/multiplexing and eCG are summarized. The list of the proposals is as follows:

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| **Topic** | **Collecting Companies’ views on whether to discuss the issue in RAN1 #104bis-e** | **FL Comment** |
| **Issue #1:** Intra-UE prioritization/multiplexing   * Continue the same discussion in the last meeting regarding to the inter-action between LCH-based prioritization and UL skipping rule. |  | Would like collect companies’ views on whether to continue the discussion before receiving any Reply LS from RAN2. |
| **Issue#2:** PHR for multiple CGs in one serving cell.   * Discuss which CG should be used for PH calculation if multiple CG PUSCHs with same starting symbol in one cell overlap with a PUSCH carrying the PHR in the other cell. |  | This issue was proposed for several meetings, check with companies whether it is OK to discuss. |
| **Other issues?** |  |  |

# 2 Issue #1

## 2.1 Summary:

* [R1-2102350] discussed the intra-UE prioritization and UCI multiplexing issues related to understanding 2 (i.e., MAC is aware of the UCI multiplexing in PHY based on UL skipping agreement) from a RAN1 perspective and propose to relax the timeline.

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| Proposal 1: When LCH based prioritization is configured, **the timeline in the following cases needs to be relaxed** e.g. by adding delta symbols to the existing values   * Case 1: UCI multiplexing timeline for the overlap between SR and PUSCH * Case 2: the timeline for the overlap between DG PUSCH and CG PUSCH |

* [R1- 2102370] proposed the feature of UL skipping with UCI and Rel-16 LCH based prioritization are not enabled simultaneously based on following observations.

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| * Observation 1: If the feature of UL skipping with UCI and Rel-16 LCH based prioritization are configured simultaneously and UL skipping with UCI is prioritized over Rel-16 LCH based prioritization, high priority data may be dropped. * Observation 2: If the feature of UL skipping with UCI and Rel-16 LCH based prioritization are configured simultaneously and Rel-16 LCH based prioritization is prioritized over UL skipping with UCI, additional spec impact is observed and the information of UCI multiplexing is useless for MAC to determine which MAC PDU to generate and deliver. |
| **FL question:**  About the feature of UL skipping with UCI and Rel-16 LCH based prioritization are not enabled simultaneously, I wondered whether it can solve the problem of BD at gNB side and processing timeline at UE side. For example, taking case 4a in appendix, when UL skipping is not configured and LCH based prioritization is configured, is it correct understanding that depending on data availability, MAC can deliver either HP CG PUSCH or LP DG PUSCH. If LP DG PUSCH is delivered (due to no data available for CG), the LP PUCCH MUX on LP PUSCH; if HP CG PUSCH is delivered, then the LP PUCCH should be dropped together with the LP PUSCH or LP PUCCH is still transmitted? (if consider CA case, it seems many BDs at gNB side is still inevitable, if LP PUCCH is transmitted, then UE processing timeline needs to be relaxed?) |

* [R1-2102487] generally proposed to protect the data with high priority.

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| ***Proposal 1:*** *If CG PUSCH and DG PUSCH overlap in the time domain with same/different priorities, and one of the collided PUSCH overlaps with a PUCCH, a UE expects a MAC PDU is generated only for the PUSCH with higher priority if there is available data.*  ***Proposal 2:*** *If the MAC entity does not generate MAC PDU for a PUSCH, the PUSCH should not participate in the subsequent UCI multiplexing.*  ***Proposal 3:*** *For the LP PUCCH overlapping with a LP PUSCH which is canceled by a HP PUSCH,*   * *If the time interval between LP PUCCH and the PDCCH scheduling HP PUSCH is not less than Tmuxproc,2, the LP PUCCH should be transmitted.* * *Otherwise, the LP PUCCH should be dropped.*   ***Proposal 4:*** *If the MAC entity does not generate MAC PDU for a HP PUSCH, the HP PUSCH should not cancel the overlapped LP PUSCH or LP PUCCH.*  ***Proposal 5:*** *When there is no available data for PUSCH transmission, the PUSCH can be skipped if the PUSCH overlaps with PUCCH and they are configured with different priorities.* |

* [R1-2102592] proposed MAC layer should also take into account the UCI multiplexing in addition to LCH prioritization when decide which MAC PDU should be delivered and proposed different solutions for different collision cases.

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| **Proposal 1**: In case LCH prioritization is configured and there is resource overlapping between PUCCH and PUSCH(s) with a single PHY priority, MAC layer shall decide which MAC PDU should be delivered based on LCH prioritization and the UCI multiplexing requirements for a single PHY priority.  **Proposal 2:** In case LCH prioritization is configured and there is a single PHY priority for UL transmissions, when DG PUSCH, CG PUSCH and PUCCH overlap with each other, MAC generates PDU for the PUSCH selected to carry UCI and the UCI is multiplexed on the selected PUSCH.    Case 1 of signle PHY priority for proposal 2  **Proposal 3:** In case LCH prioritization is configured and there is a single PHY priority for UL transmissions, when DG PUSCH overlaps with both CG PUSCH and PUCCH and there is no overlapping between CG PUCCH and PUCCH:   * If the starting symbol of DG PUSCH is no later than the starting symbol of CG PUSCH, MAC always delivers PDU to DG PUSCH and UCI is multiplexed on the DG PUSCH; * If the starting symbol of DG PUSCH is later than the starting symbol of CG PUSCH, UCI is transmitted on the PUCCH if MAC delivers PDU to CG PUSCH and UCI is multiplexed in DG PUSCH if MAC delivers PDU to DG PUSCH.     Case 2 of signle PHY priority for proposal 3  **Proposal 4:** In case LCH prioritization is configured and there is a single PHY priority for UL transmissions, when DG PUSCH and CG PUSCH are overlapping on a serving cell and CG PUSCH is overlapping with PUCCH and DG PUSCH is non-overlapping with the PUCCH:   * If the starting point of PUCCH is earlier than the starting point of DG PUSCH, the same solution as for no Rel-16 LCH based prioritization could be reused;     Case 3 of signle PHY priority for proposal 4   * Otherwise, MAC could select to deliver PDU for either CG PUSCH or DG PUSCH based on Rel-16 LCH based prioritization, and UCI could be transmitted on CG PUSCH when there is PDU for CG or transmitted on PUCCH when there is no PDU for CG PUSCH.     Case 3 of signle PHY priority for proposal 4  **Proposal 5:** In case LCH prioritization is configured and there are two PHY priorities for UL transmissions, the MAC PDU generation and delivery can be handled by gNB scheduling or MAC layer.  **Proposal 6:** In case LCH prioritization is configured and there are two PHY priorities for UL transmissions which refer to the different priorities between DG PUSCH and CG PUSCH and the same priority between DG PUSCH and PUCCH, gNB should avoid scheduling such DG PUSCH overlapping with both PUCCH and CG PUSCH when DG PUSCH overlaps with both CG PUSCH and PUCCH with the starting symbol of DG PUSCH no later than the starting symbol of CG PUSCH and PUCCH doesn’t overlap with CG PUSCH.    Case 1 of two PHY priorities for proposal 6    Case 2 of two PHY priorities for proposal 6  **Proposal 7:** In case LCH prioritization is configured and there are two PHY priorities for UL transmissions which refer to the different priority between DG PUSCH and CG PUSCH and the same priority between DG PUSCH and PUCCH, when CG PUSCH transmission is earlier than scheduled DG PUSCH transmission and PUCCH doesn’t overlap with CG PUSCH:   * If MAC delivers PDU to CG PUSCH, UCI is transmitted on the PUCCH; * If MAC delivers PDU to DG PUSCH, UCI is multiplexed in DG PUSCH.     Case 3 of two PHY priorities for proposal 7  **Proposal 8:** For overlapping between DG PUSCH and CG PUSCH with different priorities, the first symbol of LP PUSCH should be no earlier than the first symbol of HP PUSCH. |

* [R1-2102741] firstly proposed design principles and provided the solutions for some collision scenarios based on the principles.

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| **Two design principles:**   1. For a give PHY priority level, the PUSCH#0 (DG or CG) expected to have UCI multiplexing is determined as if signals/channels of the other PHY priority do not exist. The UCI is either multiplexed with PUSCH#0 or transmitted via PUCCH, but not to be multiplexed a different PUSCH. 2. For any UL grant (i.e., DG-PUSCH or CG-PUSCH), if MAC does not generate a TB for a grant, then the PUSCH is discarded and does not participate in subsequent physical layer procedure.   **Scenarios and Related Processing**   1. If lch-basedPrioritization not configured, existing MAC procedure applies, i.e., DG always overrides CG for overlapping DG/CG of the same/different PHY priority. 🡺 Scenario 1) and 2) 2. If lch-basedPrioritization configured and a single PHY priority for UL transmission, the PUSCH#0 (DG or CG) expected to have UCI multiplexing is determined. UL grant of PUSCH#0 is prioritized in LCH prioritization. The UCI is multiplexed with PUSCH#0 for transmission. Scenario 3) 3. If lch-basedPrioritization configured and two PHY priorities for UL transmission, the PUSCH (HP) #0 and/or PUSCH (LP) #0 expected to have UCI multiplexing is determined. UL grant of PUSCH (HP) #0 and PUSCH (LP) #0 are prioritized in LCH prioritization. Physical layer intra-UE prioritization is applied afterwards to determine if PUSCH (LP) #0 is kept or discarded. Scenario 4) 4. If simple design principles for Scenario 3)-4) cannot be achieved, it is acceptable to forbid simultaneous configuration of UL skipping and LCH based prioritization.   In this case:   * + When UL skipping is not configured and LCH based prioritization is configured, then existing MAC and PHY procedure defined for URLLC/IIoT is followed.   + When UL skipping is configured and LCH based prioritization is not configured, then only procedure for “Scenario 2). lch-basedPrioritization not configured, and two PHY priorities for UL transmission” is needed for UL skipping. |
| **FL question:**    About When UL skipping is not configured and LCH based prioritization is configured, then existing MAC and PHY procedure defined for URLLC/IIoT is followed. I would like to clarify what is the existing MAC and PHY procedure? Taking above case 4a as example, is it correct understanding that depending on data availability, MAC can deliver either HP CG PUSCH or LP DG PUSCH. If LP DG PUSCH is delivered (due to no data available for CG), the LP PUCCH MUX on LP PUSCH; if HP CG PUSCH is delivered, then the LP PUCCH should be dropped together with the LP PUSCH or LP PUCCH is still transmitted? (if consider CA case, it seems many BDs at gNB side on where the UCI is transmitted is still inevitable?) |

* [R1-2103083] generally would like to extend the design principle of UL skipping for the case when LCH-based prioritization is configured.
  + It clarifies that the PUSCH used for UCI multiplexing based on UL skipping agreement should be hypothetical PUSCH rather than the actual PUSCH transmissions.
  + It also discussed the gNB BD complexity due to the unknown SR status and CG PUSCH.

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| **Proposal 2-1:** **in Rel-17**, when HARQ-ACK PUCCH resource and SR PUCCH resource both configured with PUCCH format 1 collide, then a PUCCH resource for HARQ-ACK with payload more than 2 bits is used, zero padding can be considered to minimize specification change & implementation change:  In this case the payload is given by [HARQ bit(s)] + SR bit + zero or more padding bit.  • If there are 2 HARQ-ACK bits, then the 1 SR bit is included in the payload, so there are 3 bits in the payload (2 HARQ-ACK bits + 1 SR bit).  • If there are 1 HARQ-ACK bit, then 1 SR bit and 1 padding bit are included, so there are 3 bits in the payload (1 HARQ-ACK bit + 1 SR bit + 1 padding bit).  **Proposal 3-1:** To mitigate the uncertainty in UCI multiplexing, the occurrence of HARQ-ACK PUCCH resource at PUCCH format 1 and SR PUCCH resource at PUCCH format 1 should be avoided. One of the following alternatives is selected:  • Alt. 1: HARQ-ACK PUCCH resource and SR PUCCH resource cannot be both configured with PUCCH format 1  • Alt. 2: If HARQ-ACK PUCCH resource and SR PUCCH resource overlap, then they won’t be both at PUCCH format 1.  • Alt. 3: SR is assumed to be negative in Stage 1.  • Alt. 4: SR is assumed to be positive in Stage 1.  **Proposal 3-2:** For PUSCH selection with hypothetical PUSCH transmissions, the following priority order is used:  o First priority: PUSCH with A-CSI as long as it overlaps with Z  o Second priority: earliest PUSCH slot(s) based on the start of the slot(s)  o If there are still multiple PUSCHs overlap with Z in the earliest PUSCH slot(s), follow the following priorities (sequentially from high to low)   * + Third priority: Dynamic grant PUSCHs > PUSCHs configured by respective ConfiguredGrantConfig > semiPersistentOnPUSCH   + Fourth priority: PUSCHs on serving cell with smaller serving cell index > PUSCHs on serving cell with larger serving cell index   + Fifth priority: Earlier PUSCH transmission > later PUSCH transmission   **Proposal 3-3: UE PHY provides the following to UE MAC:**  **• the PUSCH selected for UCI multiplexing**  **• PUCCH resource Z**  **o For a PUCCH resource Z, the following are indicated to MAC:**   * + **the starting symbol and duration (the number of OFDM symbols in the PUCCH)**   + **the UCI payload: information about SR (e.g. SR resource IDs) conveyed in resource Z, and optionally whether HARQ-ACK and/or CSI is included.**   Proposal 3-4: if some form of the RAN1 102-e agreement is to be extended to the cases with configured physical layer priority and/or lch-basedPrioritization, there can be 3 outcomes:  • Outcome 1:  • 1> if the PUSCH selected for UCI multiplexing is with UL-SCH, and MAC generates MAC PDU for the PUSCH selected for UCI multiplexing or  • 1> if the PUSCH selected for UCI multiplexing is without UL-SCH, and MAC does not generate MAC PDU for another PUSCH to overlap with the PUSCH selected for UCI multiplexing  • 2> PHY transmits the PUSCH selected for UCI multiplexing (dropping SR if SR is present in resource Z)  • Outcome 2-1:  1> if the PUSCH selected for UCI multiplexing is with UL-SCH, and MAC does not generate MAC PDU for the PUSCH selected for UCI multiplexing or  1> if the PUSCH selected for UCI multiplexing is without UL-SCH, and MAC generates SR or MAC PDU for another PUSCH to overlap with the PUSCH selected for UCI multiplexing  2> PHY checks there is no PUSCH overlapping with resource Z on the PUCCH CC or another CC  3> PHY transmits resource Z including SR  • Outcome 2-2: If neither the PUSCH selected for UCI multiplexing nor resource Z can be used by PHY (e.g. MAC does not generate MAC PDU for the PUSCH selected for UCI multiplexing, but MAC generates MAC PDU for a PUSCH overlapping with resource Z), then PHY drops UCI.  **Proposal 5-1:** To avoid the necessity for PHY to assume SR status for UCI multiplexing, RAN2 should split the LCH based prioritization between data and data from LCH based prioritization between data and SR so separate UE capabilities and RRC configurations from gNB are supported for SR/data LCH based prioritization and data/data LCH based prioritization when UL skipping is configured. |

* [R1-2103144] proposed design principles/objectives and provided the solution based on the two objectives.

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| **Two design objectives:**  (1) To ensure a deterministic UCI multiplexing behavior by a UE, and  (2) to protect the HP transmissions.  **Proposal:** To handle CGDG collisions with PUCCH overlap, a UE follows the following steps:   * Step #1: Assume no uplink skipping. For each priority, a UE determines whether UCI will be multiplexed on a PUSCH or not. * Step#2: A UE selects one PUSCH that cannot be skipped by comparing the L1 priorities of the PUSCHs in case a 2-level priority is configured for a UE. * Step#3: The MAC layer can skip other PUSCHs except the one indicated by the PHY layer. * Step #4: The PHY layer performs prioritization/multiplexing as needed.   + In case the PHY has indicated one PUSCH as non-droppable, and if there is another PUSCH overlapping with it on the same carrier, that PUSCH, including UCI that is expected to be multiplexed on it as part of step #1, are dropped. |
| **FL question**: for step 3, is it correct understanding that MAC can also skip the PUSCH indicated by the PHY layer? and in such case, if the non-droppable PUSCH, call PUSCH#1 indicated by PHY has UCI MUXed is skipped by MAC, then the UCI is dropped together with the PUSCH#1, correct? |

* [R1- 2103214] made some observations for the cases discussed in the last meeting.

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| **Observation 1:** Case 2-1(b) has the same PHY behavior regardless of understanding, while case 2-1(a) has different PHY behaviors according to understanding.  **Observation 2:** It is not clear whether a UE would multiplex AN/CSI on PUSCH or not due to negative SR on case 2-2(b) although MAC generates MAC PDU assuming PUSCH overlapping with final PUCCH resources.  **Observation 3:** It is not clear whether AN/CSI would be multiplexed with PUSCH or not due to negative SR although MAC generate MAC PDU assuming PUSCH overlapping with final PUCCH resources. |
| **FL comments: About the negative SR.** The multiplexing consequences depends on PUCCH format (PF0/1 or PF2/3/4) used for HARQ-ACK/CSI, the PUCCH format (PF0/1 or PF2/3/4) used for SR and SR status (negative or positive). For example, **if the PUCCH format for HARQ-ACK is PF2/3/4, then regardless of SR is positive or negative, the SR occupies 1 bit.** Otherwise, if the PUCCH format for HARQ-ACK is PF0/1, SR is dropped or use SR resource to Tx the HARQ-ACK if SR is positive or use HARQ resource to Tx HARQ-ACK if SR is negative, which depends on PUCCH format 0 or 1 is sued for SR. |

## 2.2 Discussions

**Discussion point 1:** Share the views that it is difficult to discuss case-by-case when LCH-based prioritization is configured. So, better to first discuss whether we have the same understanding on the following solution objectives?

* Avoid blind detection of the UCI on which PUSCH, i.e., the PUSCH multiplexing with the UCI should be deterministic
* Avoid changing existing UCI multiplexing or PUSCH preparation timeline as much as possible
* Protect the HP PUSCH transmission as much as possible

Note above design target 1 and 2 are the same as the ones for the agreements made for UL skipping in 7.1 session.

Discussion point 2:

* Based on above solution objectives, do you agree following high-level solution for CG and DG collisions with PUCCH overlap when LCG based prioritization is configured?
  + Step #1: Assume no uplink skipping. For each priority, a UE determines whether UCI will be multiplexed on a PUSCH or not.
    - Discuss if there is a HP PUSCH overlaps with a LP PUSCH#1 on the same CC#1 and there is LP PUCCH overlaps with the LP PUSCH#1 on the same or different CC, whether the LP PUSCH#1 should be excluded from the selection of the LP PUSCH for LP UCI multiplexing? E.g.,
      * For single CC case, it means the LP UCI will be transmitted on LP PUCCH
      * For CA case, if there is another LP PUSCH#2 in CC#2, then the LP PUCCH should MUX on LP PUSCH#2 on CC#2
  + Step#2: A UE selects one PUSCH that cannot be skipped by comparing the L1 priorities of the PUSCHs in case a 2-level priority is configured for a UE.
  + Step#3: The MAC layer decides which MAC PDU to generate taking into account PHY’s indication.
  + Step #4: The PHY layer performs prioritization/multiplexing as needed.
    - In case the PHY has indicated one PUSCH as non-droppable, and if there is another PUSCH overlapping with it on the same carrier and delivered by MAC layer, that PUSCH indicated by PHY, including UCI that is expected to be multiplexed on it as part of step #1, are dropped.

# 3 Issue #2

* Issue:

Multiple CG configurations are configured in cell#1. If a PUSCH in cell#2 carries PHR for cell#1, and if there are overlapped multiple CG PUSCHs with same starting symbol in cell#1, it is necessary to specify which CG PUSCH would be involved in PHR calculation.

* Proposal:

Propose to use the CG PUSCH having lowest *configuredgrantindex* if there are multiple CG PUSCHs are configured with same starting symbol.

# 4 Summary

TBD

# References

1. R1-2102350, On LCH prioritization and UL skipping, Huawei, HiSilicon
2. R1-2102370, Discussion on PHY behaviour for collision between CG and DG with UCI overlapping, OPPO
3. R1-2102487, Remaining issues on intra-UE multiplexing in Rel-16 URLLC, ZTE
4. R1-2102592, Discussion on overlapping between CG PUSCH and DG PUSCH, CATT
5. R1-2102741, Intra-UE Multiplexing and Prioritization for Rel-16 URLLC, Ericsson
6. R1-2103083, UCI multiplexing and PUSCH skipping design in URLLC, Apple
7. R1-2103144, Remaining issues on eCG enhancements for URLLC , Qualcomm Incorporated
8. R1-2103214, Discussion on PUSCH skipping for URLLC, Samsung
9. R1-2103337, PHR issues related to URLLC/IIOT WI, LG Electronics

# Appendix

R1-2102741, Intra-UE Multiplexing and Prioritization for Rel-16 URLLC, Ericsson

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| **Intra-UE Multiplexing and Prioritization based on two design principles**    Figure 2. CG, DG and PUCCH of different priority overlap in time with each other (extend case 1-3 in R1-2009772 by allowing two PHY priorities).    Figure 3. DG overlaps with PUCCH and CG, while CG doesn’t overlap with PUCCH (extend case 1-4 in R1-2009772 by allowing two PHY priorities).    Figure 4. PUCCH overlaps with DG and CG, while DG and CG do not overlap with each other (extend case 1-5 in R1-2009772 by allowing two PHY priorities).    Figure 5. CG overlaps with PUCCH and DG, but PUCCH and DG do not overlap with each other (extend case 1-6 in R1-2009772 by allowing two PHY priorities).    Figure 6. First PUCCH overlaps only with CG, second PUCCH overlaps only with DG, but CG and DG overlaps with each other. |