**3GPP TSG RAN WG1 #105-e R1- 21xxxxx**

e-Meeting, May 12th – 20th, 2021

**Agenda item:** 7.2.5

**Source:** Moderator (vivo)

**Title:** Email discussion of intra-UE multiplexing and eCG

**Document for:** Discussion and Decision

# 1 Introduction

This document is to kick-off the following email discussion:

[105-e-NR-L1enh-URLLC-04] Email discussion/approval on remaining issues on intra-UE prioritization and multiplexing – Lihui (Vivo):

* Discuss whether to confirm RAN2’s working assumption on UL skipping vs. LCH-based prioritization.
* Discuss PHY impacts/behavior on intra-UE prioritization and multiplexing.
* Discussion and decision by May 24, TPs by May 27

**Note that the deadline for the email and the potential TP is set on May 27, please provide your first-round feedback by UTC 11:59 am, May 21.**

# 2 Background

In RAN1#103-e and 104-e meeting, RAN1 received two LSs from RAN2 to confirm the intended UE behavior as below:

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| **RAN2 LS on Intra UE Prioritization Scenario (R1-2007523)**   |  | | --- | | RAN2 has agreed in RAN2#107 that  For the case when no PDU has been generated at all yet, and there are two grants where one will be de-prioritized (and there is data available for both grants), one PDU is generated by MAC.  This agreement means that in the collision scenario between CG and DG with same/different PHY-priority index, and only one transport block is delivered to PHY, PHY transmit on the grant for which a transport block is delivered and skip the transmission on the other grant.  It is not clear from the wording in the LS R1-2005078 if the PHY behavior described above is consistent with RAN1 understanding.  RAN2 respectfully asks RAN1 to clarify if the mentioned scenario is supported or not. |   **RAN2 LS on overlapped data and SR are of equal L1 priority (R1-2100026)**   |  | | --- | | RAN2 confirms the intended UE behavior: For the case of overlapping PUSCH and SR with equal L1 priority and MAC has not yet delivered MAC PDU for the PUSCH to PHY, if SR is prioritized in MAC, MAC shall not deliver the MAC PDU for the PUSCH and shall instruct PHY for SR transmission.  RAN2 respectfully asks RAN1 to confirm if the intended UE behavior mentioned above can be supported. | |

RAN1 provided the corresponding reply LSs as following:

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| **RAN1 Reply LS on Intra UE Prioritization Scenario (R1-2009680)**   |  | | --- | | RAN1 had a discussion and made following agreements:  **Agreement**   * For the collision scenario between CG and DG with same/different PHY-priority index, if there is no collision between PUCCH and the CG and there is no collision between PUCCH and the DG, the behaviour mentioned in the LS is consistent with RAN1’s understanding if taking into account the TP to Rel-16 TS 38.214, i.e., revision CR in R1-2008655. * When the MAC entity is configured with *lch-basedPrioritization*, for the collision scenario between CG and DG with same/different PHY-priority index, and when there is collision between PUCCH and the CG with the same priority and/or there is collision between PUCCH and the DG with the same priority, RAN1 is still discussing the related PHY layer behaviour. |   **RAN1 Reply LS on overlapped data and SR are of equal L1 priority (R1-2102244)**   |  | | --- | | Assumption: LCH based prioritization is configured. Rel-16 UL skipping is possible.  RAN1 respectfully asks RAN2 to provide their views on which understanding (understanding 1 or 2) is the intended MAC layer behavior or to provide an alternate understanding, for case 2-1, case 2-2, case 3 and case 4. | |

In RAN2#113-e and RAN2#113bis-e meeting, RAN2 discussed Rel-16 intra-UE prioritization with taking UL skipping agreement into account and achieved following agreements:

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| --- |
| **Working assumption: When lch-BasedPrioritization is not configured and Rel-16 CG/DG PUSCH skipping is enabled, DG always overrides CG. This working assumption is not agreed until confirmed by RAN1.**  **Working assumption: The MAC entity does not generate a MAC PDU for a deprioritized uplink grant even when its associated PUSCH is overlapping with PUCCH. This working assumption is not agreed until confirmed by RAN1.**  **Confirm the WA that LCH based prio has higher priority than UL skipping still applies, and we expect that if there are issues, RAN1 will come-back.** |

In addition, for various SR/Data overlapping cases identified by RAN1, as captured in RAN2’s chairman notes in RAN2#113bis-e meeting, it seems both understandings 1) MAC does not have a knowledge of the UCI multiplexing and 2) MAC would have a knowledge of the UCI multiplexing are possible, and RAN2 postponed the discussions to the next meetings.

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| Chair: A TS can refer to a condition where the details are specified in another TS. This is usually done by fuzzy reference, so it seems that both interpretations are possible (without adding L1 specific details in MAC or vice versa).  Chair: Understanding 1: If we assume that MAC just generate SR and let L1 decide if/by what resource to transmit it, if the SR is not transmitted in the end then MAC may need to know this, in order to re-trigger the SR.  Chair: Understanding 2: If we assume that MAC (the UE) can first know whether SR can be transmitted or not, then the current TS works.  Chair propose to: Postpone this specific issue (MAC awareness of UCI for this case), invite for a more principal discussion on MAC L1 dependencies next meeting.  **Postpone this issue** |

# 3 Discussions

Basically, there are four scenarios as below for intra-UE prioritization/multiplexing, considering both MAC lch-basedPrioritization configuration and physical layer priorities:

* Scenario #1: lch-basedPrioritization is NOT configured, and SINGLE PHY priorities for UL transmission
* Scenario #2: lch-basedPrioritization is NOT configured, and TWO PHY priorities for UL transmission
* Scenario #3: lch-basedPrioritization is configured, and SINGLE PHY priorities for UL transmission
* Scenario #4: lch-basedPrioritization is configured, and TWO PHY priorities for UL transmission

Scenario #1 is under the discussion in agenda item 7.1 (NR Maintenance of Rel-15). In this document, let’s focus on the Scenario#2 ~ #4.

## 3.1 Discussion on Scenario#2 without LCH based prioritization

[2] and [8] proposed to confirm RAN2’s WA for scenario#2. Therefore, following proposal is made:

* Proposal 3.1-1: When *lch-BasedPrioritization* is not configured and PHY is configured with two L1 priorities, RAN1 confirms RAN2’s working assumption that DG always overrides CG.

**Question 3.1-1: Do you agree above Proposal 3.1-1 in general?**

* **If no, please provide the reasons and your suggestions.**

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| Company | View |
| Nokia, NSB | Agree |

## 3.2 Discussion on Scenario#3 and #4 with LCH based prioritization

For scenario#3 and scenario#4 that when the MAC entity is configured with *lch-basedPrioritization*, for the collision scenario between CG and DG with the same/different PHY-priority index, and when there is collision between PUCCH and the CG with the same priority and/or there is collision between PUCCH and the DG with the same priority, RAN2 made WA in RAN2#113-e and confirmed that WA in RAN2#113bis-e meeting as below.

|  |
| --- |
| **@ RAN2#113-e**  **Working assumption: The MAC entity does not generate a MAC PDU for a deprioritized uplink grant even when its associated PUSCH is overlapping with PUCCH. This working assumption is not agreed until confirmed by RAN1.**  **@ RAN2#113bis-e**  **Confirm the WA that LCH based prio has higher priority than UL skipping still applies, and we expect that if there are issues, RAN1 will come-back.** |

Based on the contributions, in general, there are two views:

* V1: Working assumption should be confirmed. As for URLLC operation, for critical data, the LCH based prioritization should have higher priority than the UL skipping operation.
* V2: Working assumption should not be confirmed. Since the WA departs from the “UL skipping agreements” principle that the PUSCH with UCI multiplexing cannot be skipped.
  + [1] provides examples as shown in Figure 1(A) and 1(B), if the WA is confirmed, then issues of blind detection complexity for PUSCH with/without UCI and impacts on UE processing timeline will come back again.



Figure 1(A). If LCH based prioritization has higher priority than UL skipping, and MAC generates a PDU for DG PUSCH1, and does not generate a PDU for CG PUSCH 1 from [1].



Figure 1(B). If LCH based prioritization has higher priority than UL skipping, and MAC does not generate a PDU for DG PUSCH1, and but generate a PDU for CG PUSCH 1 from [1].

In addition, [1] also proposed another alternative that Rel-16 does not support a simultaneous configuration of the Rel-16 UL skipping and intra-UE prioritization. However, [2], [8] observed that from the collision cases as analyzed in RAN1#104-e email discussions in R1-2102151, it seems independently of the UL skipping operation, for Scenarios #3 and #4, when LCH based prioritization is configured, there will be cases that the MAC will not be able to deliver a MAC PDU for a PUSCH grant overlapping with a PUCCH carrying UCI, gNB still needs to do hypothesis testing of PUSCH-UCI multiplexing. It may be good to first clarify this point.

We can still take above Figure 1(A) and Figure 1(B) as examples. **Assuming UL skipping is NOT configured and LCH based prioritization is configured**, based on the LCH priority, **buffer status (note that from MAC perspective, the priority of the PUSCH without any available data is lower than the PUSCH with available data as specified in TS 38.321)**, and considering PHY can only handle one MAC PDU on the overlapped grants, then the PUSCH that will be delivered by MAC is still not deterministic (No PDU for CG PUSCH 1 in Figure 1(A) and No PDU for DG PUSCH 1 in Figure 1(B)). The same issue as for the case when UL skipping is configured and LCH based prioritization has higher priority than UL skipping still needs to be addressed on how to handle the PUCCH that overlaps with a PUSCH with the same L1 priority, but the PUSCH is not delivered by MAC.

**Question 3.2-1: In case UL skipping is NOT configured and LCH based prioritization is configured, do you agree that there are cases that the MAC will not be able to deliver a MAC PDU for a PUSCH grant overlapping with a PUCCH carrying the UCI of the same L1 priority? And RAN1 needs to discuss on how to handle the PUCCH?**

* **If no, what is your views/reasons?**

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| Company | View |
| Nokia, NSB | Agree |

For Scenario#3 and #4 that LCH based prioritization is configured, contributions [1], [4], [5], [6], [8] more or less proposed to extend the principle of UL skipping agreements to address the concern of the hypothesis testing of PUSCH-UCI multiplexing due to UE internal procedure (MAC) of generating a TB or not for a given PUSCH. More specifically, following design principle was proposed:

**Proposal 2: For a given PHY priority level, the PUSCH#0 (DG or CG) expected to have UCI multiplexing is determined. The UCI is either multiplexed with PUSCH#0 or transmitted via PUCCH, but not to be multiplexed with another PUSCH.**

**Question 3.2-2: In case LCH based prioritization is configured, do you support above proposal 2?**

* **If no, what is your views/reasons?**

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| Company | View |
| Nokia, NSB | No  First, the proposal is slightly unclear (i.e. what is *PUSCH#0* – and what would be *another PUSCH*)? So clarification would be needed / appreciated in the proposal itself to be agreeable.  Secondly, it is not clear to us if this ‘another PUSCH’ would be on the same CC or a different CC (i.e. CA case discussed in Question 3.2-3, is there any relation between Question 3.2-2 and 3.2.-3). So clarification or more information of this proposal (e.g. by the proponent company - I guess Ericsson in [1]) would be appreciated. |

About on how to handle the PUCCH that overlaps with a PUSCH of the same L1 priority if the PUSCH is not delivered by MAC, following options are proposed based on the contributions:

* Option 1: drop the PUCCH.
  + Which is relatively simple from UE implementation of view [5], [6].

However, [2] pointed out that “*if the UE would drop the UCI/PUCCH in the first place the UCI would be lost for any type of gNB implementation. If otherwise, the PUCCH / UCI would be transmitted a higher complexity gNB implementation could take advantage of the UCI whereas for simpler gNB implementation (not doing the blind PUCCH detection) the situation would be the same as if the PUCCH would not be transmitted (i.e. overlapping PUCCH/UCI is not received by the gNB). So there seems to be no real disadvantage of enabling the UE to transmit the related PUCCH*”. Some optimized options are proposed as in [2], [3], [4], [6], [8].

* From [2], [3], [6], [8]: the UCI may not always be transmitted on PUCCH after determining the PUSCH to be multiplexed with UCI is canceled. It depends on whether the UE has enough time to process PUCCH. The timeline condition which should be ensured by gNB for the case 1-6 in RAN1#104-e as summarized in R1-2102246 can be reused. Figure 2a, 2b and 2c give some examples.
  + Option 2: for the case that a PUSCH i.e., PUSCH#0 overlap with a PUCCH#0 with the same L1 priority on a same or different serving cell, a PUSCH i.e., PUSCH#1 overlaps with the PUSCH#0 on one serving cell and the PUSCH#1 does not overlap with the PUCCH#0, and if the PUSCH#0 is NOT delivered by MAC, when timeline condition is met,
    - If there is no other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH#0 of the same L1 priority, the UCI is transmitted on the PUCCH.
    - Otherwise, the PUCCH#0 should be dropped.

Note: above timeline condition is ensured by gNB, i.e. the ending symbol of UL grant for the PUSCH#1 should be at least  symbols before the first symbol of the earliest PUCCH#0 or PUSCH#0.



Figure 2a: single CC case

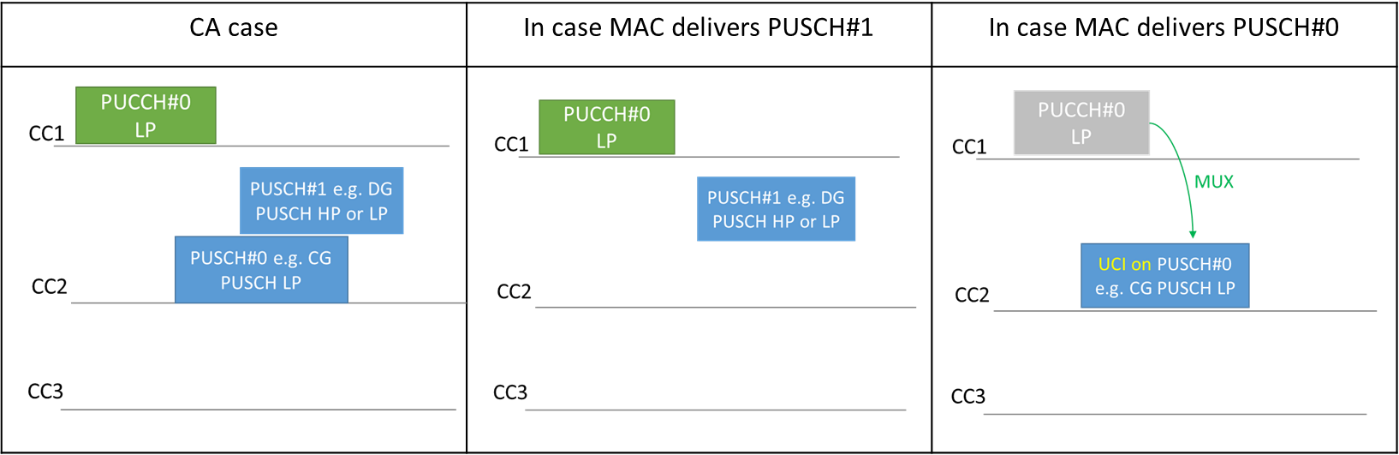


Figure 2b: CA case when there is no other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH

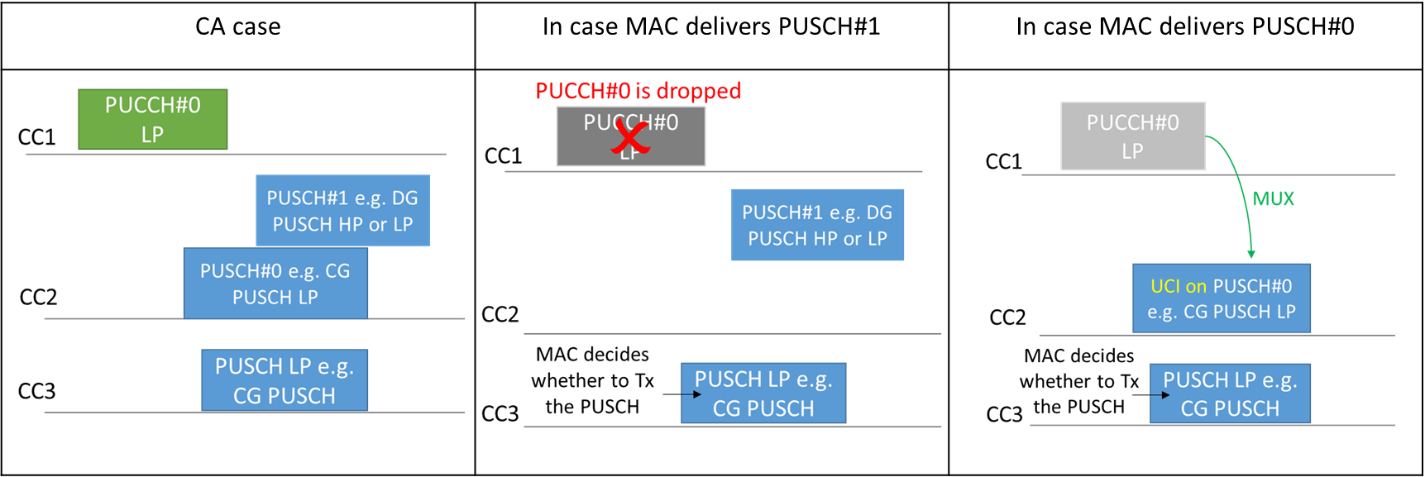


Figure 2c: CA case when there is other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH

Figure 2 examples for LP PUCCH handling when LP PUSCH is not delivered by MAC and the timeline condition is met

* From [4], Option 3
  + In case LCH prioritization is configured and there is a single PHY priority for overlapped UL transmissions, when DG PUSCH overlaps with CG PUSCH on the same serving cell,
    - When the DG PUSCH overlaps with PUCCH and the CG PUSCH does not overlaps with the PUCCH, if the PUCCH is earlier than the CG PUSCH, MAC always delivers PDU to the DG PUSCH and UCI is multiplexed on the DG PUSCH; Otherwise, it is MAC behavior to deliver PDU for either the CG PUSCH or the DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the DG PUSCH when there is PDU for the DG PUSCH or transmitted on the PUCCH when there is no PDU for the DG PUSCH.
    - When the CG PUSCH overlaps with PUCCH and the DG PUSCH does not overlap with the PUCCH, if the PUCCH is earlier than the DG PUSCH, the same solution as for no Rel-16 LCH based prioritization could be reused, e.g. case 1-6 in RAN1#104-e as summarized in R1-2104322. Otherwise, it is MAC behavior to deliver PDU for either the CG PUSCH or the DG PUSCH based on Rel-16 LCH based prioritization, and UCI is transmitted on the CG PUSCH when there is PDU for the CG PUSCH or transmitted on the PUCCH when there is no PDU for the CG PUSCH.
  + In case LCH prioritization is configured and there are two PHY priorities for overlapped UL transmissions, when DG PUSCH overlaps with CG PUSCH on the same serving cell with different priorities, the first symbol of LP PUSCH should be no earlier than the first symbol of HP PUSCH.
    - When the DG PUSCH is LP and overlaps with LP PUCCH and the CG PUSCH is HP and it does not overlap with the LP PUCCH, if the LP PUCCH is earlier than the HP CG PUSCH, gNB should avoid scheduling such LP DG PUSCH overlapping with both the LP PUCCH and the HP CG PUSCH; Otherwise, it is MAC behavior to deliver PDU for either the HP CG PUSCH or the LP DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the LP DG PUSCH when there is PDU for the LP DG PUSCH or transmitted on the LP PUCCH when there is no PDU for the LP DG PUSCH.
    - When the DG PUSCH is HP and overlaps with HP PUCCH and the CG PUSCH is LP and it does not overlap with the HP PUCCH, if the HP PUCCH is earlier than the LP CG PUSCH, MAC always delivers PDU to the HP DG PUSCH and UCI is multiplexed on the HP DG PUSCH; Otherwise, it is MAC behavior to deliver PDU for either the LP CG PUSCH or the HP DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the HP DG PUSCH when there is PDU for the HP DG PUSCH or transmitted on the PUCCH when there is no PDU for the DG PUSCH.

**From moderator’s perspective, if there is/are solution(s) that can (1) confirm RAN2’s WA for data vs. data with the same/different L1 priorities when LCH based prioritization is configured, and (2) address the concern of the hypothesis testing of PUSCH-UCI multiplexing at certain level, then we should go for such solution(s). Therefore, above option 1 and option 2 is preferred compared to option 3, since for option 3, RAN2’s WA cannot be always applied for the case when there is a single PHY priority for overlapped UL transmissions.**

**Question 3.2-3: In case LCH based prioritization is configured and LCH based prioritization has higher priority than UL skipping operation, for the case that a PUSCH i.e., PUSCH#0 overlap with a PUCCH#0 with the same L1 priority on a same or different serving cell, a PUSCH i.e., PUSCH#1 overlaps with the PUSCH#0 on one serving cell with the same or different priorities and the PUSCH#1 does not overlap with the PUCCH#0, and if the PUSCH#0 is NOT delivered by MAC, which option do you prefer to handle the PUCCH#0?**

* **Option 1: Drop the PUCCH#0.**
* **Option 2: When timeline condition is met,** 
  + **If there is no other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH#0 of the same L1 priority, the UCI is transmitted on the PUCCH.**
  + **Otherwise, the PUCCH#0 should be dropped.**

**Note: above timeline condition is ensured by gNB, i.e. the ending symbol of UL grant for the PUSCH#1 should be at least**  **symbols before the first symbol of the earliest PUCCH#0 or PUSCH#0.**

* **Option 3: Transmit PUCCH#0 and the UE does not expect that there is other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH#0 of the same L1 priority.**
* **Option 4: Other options?**

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| Company | View |
| Nokia, NSB | Option 2  As discussed in our contribution, dropping the PUCCH as for Option 1 does not really provide any advantages (as gNB can still decide not to look for the PUCCH in case of Option 2 – i.e. not receive the UCI). Option 3 would lead to linking operation for different serving cells, which is clearly not preferred. |

**Other issues that you would like to discuss, please fill in the following table.**

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| Company | View |
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## 3.3 Collision between SR and Data

### Background

Given RAN2 has not made the decision and postponed the reply LS on collision between the SR and data, it may be better for us to first discuss some RAN1 specific issues.

Following Table 1 gives the summary for Rel-15 NR SR multiplexing with other UCI(s), i.e., HARQ-ACK and CSI. Note that in Rel-15 and 16 without configuring LCH based prioritization, for the same L1 priority between the SR and PUSCH, there is no such case that the SR is still triggered and positive when it overlaps with the PUSCH. As observed in Table 1, in Rel-15, when both SR and HARQ-ACK is configured with PUCCH format 1 (PF1) and their resources are overlapping, gNB needs to do blind detection on the PUCCH resource (SR PUCCH resource or HARQ-ACK PUCCH resource), since gNB is not aware of the SR status (positive or negative). Similar BD is required at the gNB side for positive SR and the PUSCH with A-CSI or SP-CSI only transmission.

Table 1: Summary of Rel-15 SR multiplexing with other UCIs

|  |  |  |  |
| --- | --- | --- | --- |
|  | | **SR** | |
| PUCCH format (PF) PF0 | PF1 |
| **HARQ-ACK** | PF0 | Transmit HARQ-ACK/SR on PF0 for HARQ-ACK | |
| PF1 | * Transmit HARQ-ACK on PF1 for HARQ-ACK * Drop SR | * Transmit HARQ-ACK on * PF1 for HARQ-ACK, for negative SR; * PF1 for SR, for positive SR |
| PF2 | Transmit HARQ-ACK/SR on HARQ-ACK PUCCH resource (\*) | |
| PF3 |
| PF4 |
| **SR** | PF0 | * Transmit one positive SR * Which SR is transmitted is up to UE | |
| PF1 |
| **CSI** | PF2 | Transmit CSI/SR on CSI PUCCH resource (\*) | |
| PF3 |
| PF4 |
| **PUSCH** | UL-SCH | Transmit PUSCH and drop positive SR | |
| A/SP-CSI | Transmit positive SR and drop PUSCH | |
| UL-SCH + A-CSI | Transmit PUSCH and drop positive SR | |
| (\*) When K SR occasions are collided, bits are transmitted, which means that only one positive SR is allowed | | | |

For Rel-16 in case LCH-based prioritization is configured, as provided in one example in Figure 2 [6] that HARQ-ACK PUCCH resource, SR PUCCH resource i.e., SR1 for SR configuration#1 and SR PUCCH resource for SR configuration#2 i.e., SR2 are configured with PUCCH format 1, [6] pointed out that depending on SR status for the two SR configurations, 4 cases can arise:

1. Both SR1 and SR2 are negative, HARQ-ACK is sent on PUCCH-0
2. SR1 is positive and SR2 is negative, HARQ-ACK is sent on PUCCH-1
3. SR2 is positive and SR1 is negative, HARQ-ACK is sent on PUCCH-2
4. Both SR1 and SR2 are positive, HARQ-ACK is sent on PUCCH-1, and SR2 is sent over PUCCH-2.

Timeline

Description automatically generated

Figure 4 Resource selection for PUCCH format 1 from [6]

[6] observed that above uncertainty does not incur complexity on the UE side, as the UE PHY performs all the processing with information on SR status from MAC, the PHY is never tasked to track all the alternative outcomes. However, it may cause much complexity at the gNB side, since gNB cannot control the SR status at a UE, blind detection on the gNB side for different outcomes is inevitable. The complexity may increase drastically in case the SR&HARQ further overleaps with the PUSCH for case 2, 3 and 4 as discussed in R1-2102244. Therefore, [6] proposed following:

**Proposal 4: 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 for UCI multiplexing.**
* **Alt. 4: SR is assumed to be positive for UCI multiplexing.**

**Question 3.3-1: What is your views on above proposal 4 for**

* **Rel-15/Rel-16 without LCH-based prioritization?**
* **Rel-16 with LCH-based prioritization (especially considering the cases listed in the Rely LS R1-2102244)?**
* **What is your preferred Alternative if the UCI multiplexing uncertainty is an issue for Rel-15 or Rel-16 with/without LCH-based prioritization?**

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| Company | View |
| Nokia, NSB | We are a bit wondering if the **restriction** would only need to apply, if **more than one no-overlapping SR PF1 resource is overlapping with the HARQ-ACK PF1 resource** (as shown in the Figure 4), as just the overlap of only a single SR and HARQ-ACK PF1 resource is supported in Rel-15 already.  Moreover, it is unclear us for Alt. 3 & Alt. 4 which SR (as 2 overlapping SRs are to be considered) is assumed to be negative or positive.  So maybe Proposal 4 may need some related update to really try to capture the essence of Figure 4 and clarifying better Alt. 3 & 4 before being able to provide our preference. |

For the case that only SR overlaps with PUSCH of equal L1 priority, the timeline issue was discussed in the RAN1#104-e meeting, but no conclusion could be reached. [9] proposed to relax the UCI multiplexing timeline for the overlap between SR and PUSCH when LCH based prioritization is configured. The reasons are following:

* In Rel-15, when PHY receives an UL DCI scheduling UL-SCH and finds out that the scheduled UL-SCH is overlapping with SR, then PHY can start immediately with the PUSCH preparation that will contain the UL-SCH, since a positive SR will be dropped anyway when it overlaps with UL-SCH.
* But in Rel-16, if LCH based prioritization is configured, MAC can decide based on L2 prioritization, to deliver either SR or the MAC PDU. Therefore, whether PHY needs to transmit the SR or the PUSCH (containing UL-SCH) is depending on the MAC decision. It means that when PHY receives a DCI scheduling UL-SCH, it cannot immediately start to prepare the PUSCH transmission (containing UL-SCH), since it has to wait until it receives a MAC decision. An alternative handling would be that the UE anyhow starts an immediate preparation of the PUSCH, but then has to cancel it again in case that no PDU is delivered from MAC. This stopping operation requires also time and could also delay the processing.

However, [7] noted that similar case is already in Rel-15/16 in case where there are overlapping configured grant PUSCH and SR, although there is no use case where a UE transmitting SR instead of PUSCH in Rel-15. It is also noted that [R1-2104470] submitted in AI 7.1 discussed the similar issue in section 2.2 on whether/how timeline needs to be defined to give sufficient time for UE to cancel the PUSCH without UL-SCH when it overlaps with the positive SR. Although R1-2104470 did not get the email discussion, it would be good to take the issue that seems already existed in Rel-15 into account when we make the decision here.

**Question 3.3-2: What is your views on relaxing the UCI multiplexing timeline for the overlap between SR and PUSCH when LCH based prioritization is configured?**

* **For example, why it is necessary or not necessary? If it is necessary, any detailed proposals on how to define the timeline?**

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| Company | View |
| Nokia, NSB | Relaxation not necessary  We don’t see this any different than UL skipping (with no UCI multiplexing) and also there the timeline is not changed. Moreover, before having a MAC PDU delivered the potential preparation of the transmission is very much limited in the first place anyhow (i.e. DM-RS only). |

**Other issues that you would like to discuss, please fill in the following table.**

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| Company | View |
|  |  |

# 4 Summary

TBD

# References

1. [R1-2104214](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104214.zip) Intra-UE Multiplexing and Prioritization for Rel-16 URLLC Ericsson
2. [R1-2104313](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104313.zip) Rel-16 URLLC/IIoT PUSCH skipping (with LCH and/or PHY prioritization configured) Nokia, Nokia Shanghai Bell
3. [R1-2104322](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104322.zip) Remaining issues on intra-UE multiplexing in Rel-16 URLLC ZTE
4. [R1-2104479](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104479.zip) Discussion on overlapping between CG PUSCH and DG PUSCH CATT
5. [R1-2104650](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104650.zip) Remaining issues on eCG enhancements for URLLC Qualcomm Incorporated
6. [R1-2105083](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105083.zip) UCI multiplexing and PUSCH skipping design in URLLC Apple
7. [R1-2105285](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105285.zip) Discussion on PUSCH skipping for URLLC Samsung
8. [R1-2105467](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105467.zip) Maintenance on eCG enhancement and intra-UE prioritization vivo
9. [R1-2105532](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105532.zip) On LCH prioritization and UL skipping Huawei, HiSilicon

# Contribution Proposals

* [R1-2104214]

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| Observation 1: If LCH based prioritization has higher priority than UL skipping, multiple possible multiplexing/prioritization outcomes exist in each slot. This significantly increases the processing burden for both UE and gNB.    Figure 1(A). If LCH based prioritization has higher priority than UL skipping, and MAC generates a PDU for DG PUSCH1, and does not generate a PDU for CG PUSCH 1.    Figure 1(B). If LCH based prioritization has higher priority than UL skipping, and MAC does not generate a PDU for DG PUSCH1, and but generate a PDU for CG PUSCH 1.  Observation 2: If UL skipping has higher priority than LCH based prioritization, multiplexing/prioritization outcome is deterministic in each slot. This is necessary to control processing burden for both UE and gNB.    Figure 2. If UL skipping has higher priority than LCH based prioritization, the behavior is deterministic.   1. If UL skipping and intra-UE prioritization need to be supported simultaneously in Rel-16, RAN1 notify RAN2 that it is necessary to specify: UL skipping has higher priority than LCH based prioritization. 2. RAN1 notify RAN2 that it is acceptable: Rel-16 does not support a simultaneous configuration of the Rel-16 UL skipping and intra-UE prioritization. 3. For a given PHY priority level, the PUSCH#0 (DG or CG) expected to have UCI multiplexing is determined. The UCI is either multiplexed with PUSCH#0 or transmitted via PUCCH, but not to be multiplexed with another PUSCH. 4. 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. |

* [R1-2104313]

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| **Proposal 1: RAN1 to indicate to RAN2 in an LS that RAN1 supports the confirmed RAN2 working assumption *“LCH based prio has higher priority than UL skipping”.***  **Proposal 2: RAN1 to indicate to RAN2 in an LS,**   * **that RAN1 supports the RAN2 working assumption “*When lch-BasedPrioritization is not configured and Rel-16 CG/DG PUSCH skipping is enabled, DG always overrides CG*”,** * **but when *lch-BasedPrioritization* is configured, the LCH based prioritization has higher priority than DG overriding CG PUSCH, i.e. MAC should select the overlapping DG or CG PUSCH grant of higher LCH priority having data available in the buffer.**   **Proposal 3: RAN1 to indicate to RAN2 in an LS that RAN1 supports the RAN2 working assumption *“The MAC entity does not generate a MAC PDU for a deprioritized uplink grant even when its associated PUSCH is overlapping with PUCCH”* and further clarify that this working assumption should be generically applicable including operation with and without LCH based prioritization as well as one & two UL PHY priorities.**  **Proposal 4: If the UE is configured with *lch-basedPrioritization* and/or two UL PHY priorities, the UE transmits a PUCCH which overlaps with a PUSCH on the same or different serving cell in case MAC did not deliver a PDU for the PUSCH.** |

* [R1-2104322]

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| ***Observation 1:*** *The agreement of PUSCH skipping cannot be applied to the collision scenario between CG PUSCH and DG PUSCH with different priorities where one of the PUSCH overlaps with a PUCCH with the same priority.*  ***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.* |

* [R1-2104479]

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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.  **Proposal 3:** In case LCH prioritization is configured and there is a single PHY priority for overlapped UL transmissions, when DG PUSCH overlaps with CG PUSCH on the same serving cell and the DG PUSCH overlaps with PUCCH and the CG PUCCH does not overlaps with the PUCCH:   * If the PUCCH is earlier than the CG PUSCH, MAC always delivers PDU to the DG PUSCH and UCI is multiplexed on the DG PUSCH; * Otherwise, it is MAC behavior to deliver PDU for either the CG PUSCH or the DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the DG PUSCH when there is PDU for the DG PUSCH or transmitted on the PUCCH when there is no PDU for the 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 overlapped UL transmissions, when DG PUSCH overlaps with CG PUSCH on the same serving cell and the CG PUSCH overlaps with PUCCH and the DG PUSCH does not overlap with the PUCCH:   * If the PUCCH is earlier than the DG PUSCH, the same solution as for no Rel-16 LCH based prioritization could be reused; * Otherwise, it is MAC behavior to deliver PDU for either the CG PUSCH or the DG PUSCH based on Rel-16 LCH based prioritization, and UCI is transmitted on the CG PUSCH when there is PDU for the CG PUSCH or transmitted on the PUCCH when there is no PDU for the CG PUSCH.     Case 3 of signle PHY priority for proposal 4    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 overlapped UL transmissions which refer to LP DG PUSCH and HP CG PUSCH and the same priority between DG PUSCH and PUCCH, when LP DG PUSCH would overlap with HP CG PUSCH on the same serving cell and the LP DG PUSCH would overlap with LP PUCCH and the HP CG PUCCH does not overlaps with the LP PUCCH:   * If the LP PUCCH is earlier than the HP CG PUSCH, gNB should avoid scheduling such LP DG PUSCH overlapping with both the LP PUCCH and the HP CG PUSCH; * Otherwise, it is MAC behavior to deliver PDU for either the HP CG PUSCH or the LP DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the LP DG PUSCH when there is PDU for the LP DG PUSCH or transmitted on the LP PUCCH when there is no PDU for the LP DG 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 overlapped UL transmissions which refer to HP DG PUSCH overlaps with LP CG PUSCH on the same serving cell and the HP DG PUSCH overlaps with HP PUCCH and the LP CG PUCCH does not overlaps with the HP PUCCH:   * If the HP PUCCH is earlier than the LP CG PUSCH, MAC always delivers PDU to the HP DG PUSCH and UCI is multiplexed on the HP DG PUSCH; * Otherwise, it is MAC behavior to deliver PDU for either the LP CG PUSCH or the HP DG PUSCH based on the Rel-16 LCH prioritization, and UCI is transmitted on the HP DG PUSCH when there is PDU for the HP DG PUSCH or transmitted on the PUCCH when there is no PDU for the 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. |

* [R1-2104650]

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| **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. |

* [R1-2105083]

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| **Observation 2-1: Channel selection with PUCCH Format 1 brings much complication to UCI multiplexing.**  **Observation 2-2: In Rel-15, PUSCH selection procedure clarified by Step 2 in the RAN1 #97 clarification applies to actual PUSCH transmissions.**  **Observation 2-3: DG PUSCHs, CG PUSCHs, and PUSCHs configured by semiPersistentOnPUSCH are candidates for UCI multiplexing. And a PUSCH without MAC PDU can be selected for UCI multiplexing.**  **Observation 2-4: Using a few examples with overlapping channels in discussion is helpful to understand the complex nature of the underlying design issue, but the complex nature of UCI multiplexing cannot be adequately covered by them.**  **Observation 2-5: There is an unremovable uncertainty in PUSCH selection for UCI multiplexing once CG configuration is activated.**  **Observation 3-1: when discussing the interaction between PHY and MAC, the demarcation between hypothetical PUSCH transmissions and actual PUSCH transmissions is key.**  **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:**   * + **First priority: PUSCH with A-CSI as long as it overlaps with Z**   + **Second priority: earliest PUSCH slot(s) based on the start of the slot(s)**   + **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**   + **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**   * + - 1. **2> PHY checks there is no PUSCH overlapping with resource Z on the PUCCH CC or another CC**       2. **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- 2105285] made some observations for the SR vs. data cases:

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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. |

* [R1- 2105467]:

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| **For collision between data and data**  **Proposal 1: When lch-BasedPrioritization is not configured and PHY is configured with two L1 prioritizes, RAN1 confirms RAN2’s working assumption** **that is DG always overrides CG.**  **Proposal 2: When the MAC entity is configured with *lch-basedPrioritization*, for the collision scenarios between CG and DG, CG and CG with different L1 priorities and when there is collision between L1 LP PUCCH and L1 LP PUSCH and there is no collision between L1 HP PUCCH and L1 HP PUSCH, confirm RAN2’s working assumption that LCH based prio has higher priority than UL skipping.**   * **If LP PUSCH is delivered, the LP PUCCH is multiplexed on the LP PUSCH;** * **Otherwise, the handling of LP PUCCH is down-selected from following options:**   + **Opt.1: LP PUCCH is dropped together with the LP PUSCH.**   + **Opt.2: define condition X, if X is satisfied, LP UCI is transmitted on LP PUCCH; otherwise, the LP PUCCH is dropped together with the LP PUSCH.**     - **FFS X**   **Proposal 3: When the MAC entity is configured with lch-basedPrioritization, for the collision scenarios between CG and DG, CG and CG with different L1 priorities and when there is collision between L1 HP PUCCH and L1 HP PUSCH and there is no collision between L1 LP PUCCH and L1 LP PUSCH, it is preferred from RAN1 perspective that MAC shall deliver the HP PUSCH when there is HP PUCCH overlapping with the HP PUSCH regardless whether there is available data for HP PUSCH.**  **Proposal 4: When the MAC entity is configured with lch-basedPrioritization, for the collision scenarios between CG and DG, CG and CG with different L1 priorities and when there is collision between L1 HP PUCCH and L1 HP PUSCH and there is also collision between L1 LP PUCCH and L1 LP PUSCH, it is preferred from RAN1 perspective that MAC shall deliver the HP PUSCH when there is HP PUCCH overlapping with the HP PUSCH regardless whether there is available data for HP PUSCH.**   * **PHY drops the LP PUSCH and transmits the LP UCI on LP PUCCH.**   **For collision between data and SR are of equal L1 priority**  **Observation 1: No RAN1 impacts is identified for case 2-1 regardless which understanding is the current MAC layer behaviour.**  **Observation 2: for case 2-2, regardless of which understanding is correct MAC behavior, if MAC delivers SR, there are potential RAN1 impacts in terms of processing timeline at the UE side and blind detection at the gNB side.**  **Observation 3: for case 3, regardless of which understanding is correct MAC behavior, if SR is delivered by MAC, the handling of the AN/CSI that overlaps with the PUSCH can adopt the similar way as for the collision between data and data.**  **Observation 4: for case 4, if understanding 1 is correct MAC behaviour, there is no RAN1 impacts; if understanding 2 is correct MAC behaviour and SR is delivered by MAC, there are potential RAN1 impacts in terms of processing timeline at the UE side and blind detection at the gNB side.**  **Proposal 5: if RAN1 can have common understanding on above observations, discuss from RAN1 perspective, which understanding of MAC layer behavior is preferred and send LS to RAN2 about RAN1’s preference.** |

* [R1- 2105532]:

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| ***Observation 1: For understanding 2, PHY needs to inform MAC about the final PUCCH resources assuming a positive SR, then MAC decides to deliver SR or PDU. If it delivers the PDU, the UE may need to perform UCI multiplexing again based on a negative SR which would complicate the UE implementation in the physical layer.***  ***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***   ***Observation 2: In CA case, if logical channel prioritization is enabled, it is up the UE’s MAC to decide if a PDU for a PUSCH is delivered to PHY or not. The gNB might not know which PUSCH contains the UCI and has to perform blind decoding to find out.*** |