**3GPP TSG RAN WG1 #106-e**  **R1- 210xxxx**

e-Meeting, August 16th – 27th, 2021

**Agenda item:** 7.2.5

**Source:** Moderator (vivo)

**Title:** Summary of [106-e-NR-L1enh-URLLC-05] Issue#9: Remaining issues on UL prioritization and UL skipping

**Document for:** Discussion and Decision

# 1 Introduction

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

* [106-e-NR-L1enh-URLLC-05] Issue#9: Remaining issues on UL prioritization and UL skipping by August 20 - Lihui (vivo)

**Please provide your feedback by UTC 11:59 AM, August 18.**

# 2 Background

## 2.1 For collision between DG and CG

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

|  |  |
| --- | --- |
| **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. | |

RAN1 provided the corresponding reply LS 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. | |

In RAN2#113-e and RAN2#113bis-e meeting, RAN2 further 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.** |

## 2.2 For collision between SR and PUSCH

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

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| **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 LS as following:

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| **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#114-e meeting, RAN2 send the Reply LS on overlapped data and SR with equal L1 priority as follows.

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| RAN2 would like to appreciate the LS on overlapped data and SR are of equal L1 priority (R1-2102244). RAN2 has discussed and concluded the following.  For case 2-1 and case 4, RAN2 has made the following agreement in RAN2#114-e:   |  | | --- | | * We go with Understanding 1: MAC does not use knowledge of UCI multiplexing when MAC executes LCH based prioritization and deciding when to transmit SR |   For case 2-2 and case 3, RAN2 has made the following working assumption in 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. |   It was further confirmed in 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. |   The intended MAC layer behaviour of the working assumption is Understanding 2. |

# 3 Discussions

Continue the discussion in the last RAN1 meeting for the following three Scenarios for intra-UE prioritization/multiplexing:

* 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

Note that UE behavior for Scenario #1 of lch-basedPrioritization is NOT configured, and SINGLE PHY priorities for UL transmission is already finalized in the last RAN1 meeting.

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

For Scenario#2, the main issue is whether to confirm RAN2’s WA. The concerns raised in the last meeting for not confirming the WA were that it may create some PHY layer issues if the L1 priority is not visible in MAC layer in case *lch-BasedPrioritization* is not configured. However, some companies think that the UE behavior is the same as scenarios 1 and proper gNB’s configuration/scheduling can avoid the undesirable cases. Based on the submitted contributions, there are two options proposed.

**Proposal 3.1-1: When *lch-BasedPrioritization* is not configured and PHY is configured with two L1 priorities, down-select from following two options:**

* **Option 1: RAN1 confirms RAN2’s working assumption that DG always overrides CG.**
* **Option 2: RAN1 confirms RAN2’s working assumption that DG always overrides CG for the case that the DG and CG has the same L1 priority and the case that the DG has higher L1 priority than the CG.**
  + **UE does not expect to receive DG PUSCH with priority index 0 if it overlaps with CG PUSCH with priority index 1 when *lch-BasedPrioritization* is not configured and PHY is configured with two L1 priorities.**

**Question 3.1-1:**

1. **Which option do you prefer?**
2. **Can you accept the option 2 if we cannot converge on option 1?**

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| Company | View |
| HW/HiSi | Option 1 is preferred.  For the sub-bullet under Option 2, could you please clarify if it means that the UE shall not receive LP DG PUSCH if it overlaps with HP CG, or does it mean that the gNB should ensure that a LP DG PUSCH should not overlap with a HP CG? |
| CATT | We prefer Option2 |
| OPPO | We are ok with both option 1 and option 2 with slight preference to option 2, since it can protect HP data as much as possible. |

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

For scenario#3 and scenario#4 where the MAC entity is configured with *lch-basedPrioritization*, and there is collision between CG and DG with the same/different L1 priority, and there is also collision between PUCCH and the CG or DG with the same L1 priority, RAN2 made the WAs that the MAC entity does not generate a MAC PDU for a deprioritized uplink grant even when its associated PUSCH is overlapping with PUCCH. The main concern for not confirming the working assumption is that it is likely to increase gNB blind detection probability.

Some companies proposed to not configure the lch-basedPrioritization and UL skipping at the same time [2], [6]. They observed that in current specification of PHY layer multiplexing/prioritization procedure, when UL skipping function is NOT enabled, the selection of PUSCH for UCI multiplexing is performed after PHY receives PDU from MAC. However, when UL skipping function is enabled, physical layer multiplexing/prioritization procedure is based on hypothetical PUSCH, i.e., PHY performs the multiplexing without waiting for MAC’s delivering result.

Some companies observed that in Rel-15, the selection of PUSCH for UCI multiplexing is based on the actual PUSCH which is clarified in the chairman’s notes of RAN1 #97; For Rel-16 without physical layer priority or lch-basePrioritization, the selection of PUSCH for UCI multiplexing is based on the hypothetical PUSCH, aligned with the RAN1 #102-e UL skipping agreement [9].

Some companies think gNB can control blind detection complexity by proper configure the lch-basedPrioritization and UL skipping function, no need to restrict the high-capable gNB [4], [8];

Some companies think that gNB blind detection is still not reduced for some cases even if the two features are not configured simultaneously, e.g., the case with multiple overlapping CG PUSCHs in same/different serving cells, the Case 4 in Annex that no resource overlapping between SR and PUSCH, but the final PUCCH resource after UCI multiplexing overlaps with the PUSCH, given MAC does not use knowledge of UCI multiplexing and not aware of the final PUCCH resource with the SR [4], [8] (with details in following section 3.3).

To have a better understanding, one point needs to be clarified first.

**Question 3.2-1: What is your understanding of PUSCH that selected for physical layer multiplexing/prioritization in Rel-16 specification of TS 38.213 section 9? Based on your selected options, any spec update is necessary?**

* **Option 1: Actual PUSCH that delivered by MAC** 
  + **Any spec update is needed for option 1?**
* **Option 2: Hypothetical PUSCH, that may or may not be delivered by MAC**
  + **Any spec update is needed for option 2?**
* **Option 3: If UL skipping feature is NOT enabled, actual PUSCH; Otherwise, hypothetical PUSCH.** 
  + **Any spec update is needed for option 3?**

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| Company | View |
| HW/HiSi: | Option 1 without spec update.  If any option involving the hypothetical PUSCH would be selected, then it needd to be clarified whether the UCI is dropped or not if no PDU is received. Option 2 and Option 3 would therefore need a spec change. |
| Apple | Option 3 (we provide discussion on that in Section 2 and Section 3 in our contribution R1-2107714). |
| CATT | In principal, we are fine with Option 1.  In addition, for below case, we propose that UE starts the preparation of PUCCH#0 before UE knows there is PDU for PUSCH#0 to ensure UCI successful transmission. |
| OPPO | If UL skipping has higher priority than lch-basedPrioritization, then it’s hypothetical PUSCH. Otherwise, it’s actual PUSCH. |

As observed, even if the lch-basedPrioritization and UL skipping are not configured at the same time, when lch-basedPrioritization is configured without configuring the UL skipping, the BD at the gNB side still cannot be reduced. If gNB would like to reduce the BD, it should make proper scheduling, trying to avoid the undesirable collision cases. From moderator perspective, the gNB’s BD concern for not confirming RAN2’s working assumption is not really there. Hence, it is proposed to confirm RAN2’s WA.

**Proposal 3.2-2: RAN1 confirms RAN2’s following WA:**

* **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.**

**Question 3.2-2: Do you agree above proposal?**

* **If you do not agree, please provide your reasons and compromised proposal is highly appreciated.**

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| Company | View |
| HW/HiSi | Agree |
| CATT | We can confirm RAN2’s WA. |
| OPPO | We agree to confirm RAN2’s WA. If there is some concern on gNB’s blind decoding, the following compromised proposal which protect HP data/UCI as well as reducing gNB’s blind decoding to some acceptable level can be considered:   * ***If the PHY priority of the PUSCH with UCI overlapping is higher or equal to the PHY priority of the PUSCH without UCI overlapping, then UL skipping is prioritized over lch-basedPrioritization;*** * ***Otherwise, lch-basedPrioritization is prioritized over UL skipping.*** |

Some companies discussed on how to handle the PUCCH that overlaps with a PUSCH of the same L1 priority if the PUSCH is not delivered by MAC. From moderator’s understanding, depending on the discussion results of **Question 3.2-1**, if the selected PUSCH for UCI multiplexing is the actual PUSCH, then we do not need to discuss this issue. On the other hand, if for some cases, the selected PUSCH for UCI multiplexing is the hypothetical PUSCH, we need to discuss this issue. Following options proposed in email summary R1-2106025 in the last meeting can be a good starting point:

**Question 3.2-3: In case LCH based prioritization is configured, for the case that a PUSCH i.e., PUSCH#0 overlaps 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 |
| HW/HiSi | Our preference is Option 4 as given below, this option does not need a spec change.   * If there is no remaining PUSCH(s) on any serving cell overlapping with PUCCH#0 of the same priority, the UCI is transmitted on the PUCCH * Otherwise, the UCI is multiplexed in the PUSCH according to existing rules |
| Apple | We are fine with Option 2 and Option 1. |
| CATT | We are fine with Option 3.  For Option 1, dropping PUCCH#0 isn’t preferred because UCI dropping increases DL transmission latency.  For Option2, the PUCCH#0 will still be dropped if other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH#0 of the same L1 priority.  For Option 3, some scheduling restrictions on gNB for PUSCH scheduling are introduced, the while PUCCH#0 dropping can be avoided.  For Option4, although the PUCCH#0 can be transmitted in other remaining PUSCH(s) on any serving cell(s) overlapping with the PUCCH#0 of the same L1 priority, it potentially increases the blind detection efforts at the gNB side. |
| OPPO | Since this discussion has some dependency on the above questions, we prefer to postpone the discussion until companies reach common understanding on Question 3.2-1. |

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

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

[3], [4], [8], [9], [10] observed that the gNB’s blind detection is unavoidable and cannot be reduced for some cases given that MAC does not use knowledge of UCI multiplexing when MAC executes LCH based prioritization and decides when to transmit SR. In particular,

* [8] observed that for all the identified cases in terms of PUSCH and SR in the RAN1/RAN2 LSs, requiring MAC to deliver a PDU for an UL grant overlapping with a PUCCH carrying AN/CSI also for LCH based prioritization operation is not reducing the maximum number of transmission hypothesis the gNB needs to be accounting for (as the maximum is determined by case 4 where there is not overlap of PUCCH with AN/CSI and PUSCH). Case 4 is also the most complex in terms of gNB operation, as two different RE mapping hypothesis of UL-SCH on PUSCH need to be considered. There are four possibilities:



**Figure 1: Case 4**

* + (i) PUCCH carrying AN/CSI only on the green resource (no SR, PUSCH skipped since no any overlapping PUCCH with PUSCH)
  + (ii) PUCCH with SR/AN/CSI on the beige resource (SR delivered, PUSCH not delivered)
  + (iii) PUCCH carrying AN/CSI (on the green resource) and PUSCH without UCI if PUSCH is delivered but SR is not delivered
  + (iv) PUSCH carrying AN/CSI if both PUSCH and SR have been delivered since MAC is not aware of the final PUCCH resource with the SR
* [9] observed that such 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.

Based on the contribution, there is no one proposed to NOT to support the intended UE behavior mentioned in RAN2’s LS R1-2100026 on overlapped data and SR are of equal L1 priority. Therefore, following is proposed:

**Proposal 3.3-1: RAN1 confirms that the following intended UE behavior can be supported:**

* **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.**

**Question 3.3-1: Do you agree above proposal?**

* **If you do not agree, please provide your reasons and compromised proposal is highly appreciated.**

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| --- | --- |
| Company | View |
| HW/HiSi | Agree |
| CATT | We are fine with FL proposal. |

In addition, [9] discussed that in case LCH-based prioritization is configured, since gNB cannot control the SR status at a UE, it may cause much complexity at the gNB side. One example is shown in Figure 2 where the PUCCH resource for HARQ-ACK, SR1 of SR configuration#1 and SR2 of SR configuration#2 are all configured with PUCCH format 1. 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 2 Resource selection for PUCCH format 1 from [9]

Therefore, [9] proposed following to avoid the uncertainty created by overlapping PUCCH resources for HARQ-ACK/SR at PUCCH format 1:

**Proposal 3.3-2: 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.**

Above issue was discussed in the last meeting, and there were views that the proposal is not necessary since the configuration and UCI multiplexing is under gNB’s control. While there were also views that this proposal is needed and beneficial, more time should be given for companies to check. To proceed, following question is asked:

**Question 3.3-2: What is your views on above proposal?**

* **Whether it is needed and if it is needed, which is your preferred Alternative?**

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| --- | --- |
| Company | View |
| HW/HiSi | Our view is that the situation can be solved by gNB implementation. The proposal does not seem to be needed. |
| Apple | Maybe adding one point to the point FL captured on our observation: for the case with UL skipping, “(For scenarios treated in Section 2), note the uncertainty in the resource Z generation does not incur complexity on the UE side, as the UE PHY performs all the processing with information on SR status from MAC, the UE PHY is never tasked to track all the alternative outcomes, and the gNB takes all the burden to handle all possible outcomes. The situation changes drastically for the discussion in Section 3 (with UL skipping cases)”. For the case without UL skipping, it is indeed a gNB implementation issue, for the case with UL skipping, it can be a nightmare for UE implementation: as all the possible combinations need to be covered by UE implementation. Still with the example given above, then the UE PHY needs to track all the possible outcomes for UCI multiplexing, by assuming SR statuses for different SR resources. We don’t think that is reasonable to given such a job to UE when the overall design goal is to reduce gNB blind detection complexity.  If you look at the Alt. 1 to Alt. 4, they are just various ways to avoid tracking multiple hypotheses on SR statuses on the UE side. We would be fine with any of them.  In Section 5 of R1-2107714, we also provide one alternative design where the LCH based prioritization is split into data/data prioritization and data/SR prioritization, as long as data/SR prioritization is not configured, then actual SR statuses can be generated by UE MAC, so the problem to track multiple hypotheses due to SR statuses is avoided. Note RAN2 needs to change its specification (currently once LCH based prioritization is configured, it applies for data/data and data/SR). |
| CATT | In our understanding, this behavior of the occurrence of HARQ-ACK PUCCH resource at PUCCH format 1 and SR PUCCH resource at PUCCH format 1already exists in Rel-15 and it is not necessary to make any enhancement during Rel-16 maintenance. The UE behavior of maintaining Rel-15 will still work. In the case of combining with LCH, too much blind detection can be avoided by gNB scheduling and it belongs to gNB implementation. It should be noticed, no matter what gNB configuration or implementation is used, it already supported at the UE side in current specification.  Regarding the behavior for the overlapping of SR PUCCH and HARQ-ACK PUCCH, to our understanding, if there is no P-SR at the latest preparation time of A/N, UE will prepare for the A/N transmission according to N-SR, which then gives a guideline for MAC to decide the deadline to deliver P-SR to PHY.  So we think Proposal 3.3-2 isn’t necessary. |
| OPPO | In our understanding, the PHY UCI multiplexing procedure is performed based on actual SR status even with UL skipping. Seems this proposal is unnecessary. |

**out**

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

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| Company | View |
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# References

1. [R1-2106487](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106487.zip) Remaining issues on UL prioritization and UL skipping Huawei, HiSilicon
2. [R1-2106675](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106675.zip) Intra-UE Multiplexing/Prioritization and UL Skipping Ericsson
3. [R1-2106731](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106731.zip) Remaining issues on intra-UE multiplexing in Rel-16 URLLC ZTE
4. [R1-2106861](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106861.zip) Discussion on PUSCH skipping for URLLC Samsung
5. [R1-2106930](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106930.zip) Discussion on overlapping between CG PUSCH and DG PUSCH CATT
6. [R1-2107269](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107269.zip) Remaining issues on intra-UE prioritization or multiplexing OPPO
7. [R1-2107319](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107319.zip) Remaining issues on eCG enhancements for URLLC Qualcomm Incorporated
8. [R1-2107556](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107556.zip) Rel-16 URLLC/IIoT PUSCH skipping (with LCH and/or PHY prioritization configured) Nokia, Nokia Shanghai Bell
9. [R1-2107714](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107714.zip) UCI multiplexing and PUSCH skipping design for eURLLC Apple
10. [R1-2107984](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107984.zip) Maintenance on intra-UE prioritization and multiplexing vivo

Annex 1: RAN1 use cases for SR colliding PUSCH



Case 2-1: the final PUCCH resource after UCI multiplexing does not overlap with PUSCH



Case 2-2: the final PUCCH resource after UCI multiplexing overlaps with PUSCH



Case 3: other UCI(s) overlaps with a PUSCH, SR overlaps with the PUSCH, SR does not overlap with other UCI(s)



Case 4: other UCI(s) overlaps with SR of an equal L1 priority, but SR does not overlap with the PUSCH of an equal L1 priority