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

**August 16th – 27th, 2021**

**Agenda item:** 7.2.5

**Source:** Moderator (Qualcomm)

**Title:** Summary of [106-e-NR-L1enh-URLLC-06] Issue #10: UE Procedures for UCI Multiplexing and Prioritization

**Document for:** Discussion and Decision

# 1 Introduction

This document presents the companies proposals and discussions regarding the following email discussion:

* [106-e-NR-L1enh-URLLC-06] Issue#10: UE Procedures for UCI Multiplexing and Prioritization by August 20 - Kianoush (Qualcomm)

# 2 First Round of Discussions

In RAN1 #105e, the following options were considered:

* **Option 2: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.** 
  + **Any HP channel that overrides or overlaps with a HP channel that overlaps with a LP channel shall meet the cancellation timeline, namely all HP DCIs must arrive *Tproc,2+d1* before the earliest symbol that would be cancelled by the ~~final~~ HP channel.**
  + **All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels.**
* **Option 3: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:** 
  + **the UE checks overlapping between HP and LP channel for each HP grant it receives, including any intermediate HP channel that results from UCI multiplexing and PUCCH overriding triggered by each of the HP grant.**
* **Option 3a: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:** 
  + A UE checks the overlap between a HP channel and a low priority channel before multiplexing. If there is an overlap, the LP channel gets cancelled. If not, a UE performs multiplexing across the HP PUCCH channels. If then there is an overlap with a LP channel, the LP channel gets cancelled. Then, multiplexing between PUCCH and PUSCH is performed. If then there is an overlap with a LP channel, the LP channel gets cancelled
* **Option 4: whether the intermediate HP channels is used to cancel the LP channels is left to UE implementation.**

**Question #1: Which of the four options do you support? Please provide your response in the table below.**

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| **Company** | **Supported Option** |
| **Samsung** | **Option 2’**   * **Option 2’: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.**    + **~~Any HP channel that overrides or overlaps with a HP channel that overlaps with a LP channel shall meet the cancellation timeline, namely all HP DCIs must arrive~~ *~~Tproc,2+d1~~* ~~before the earliest symbol that would be cancelled by the final HP channel.~~**   + **If a UE detects a first DCI format indicating a first resource for a PUCCH transmission with corresponding HARQ-ACK information in a slot and also detects at a later time a second DCI format indicating a second resource for a PUCCH transmission with corresponding HARQ-ACK information in the slot, UE does not expect the second resource starts earlier than the start of the first resource.**   + **All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels.**   Option 2’ defines a deadline for HARQ-ACK overriding. As shown in the figure [1] below, UE cannot determine the deadline for HARQ-ACK overriding if the result PUCCH (PUCCH 2) can start earlier. On the contrary, for Option 2’ UE can determine the HARQ-ACK overriding deadline when UE determines PUCCH1. The deadline can be determined as N3 symbols before the starting of PUCCH1 (S0 in the figure). UE can wait until the deadline to perform HARQ-ACK overriding and the intermediate multiplexing during the HARQ-ACK overriding procedure can be avoided. The implementation can thus be simplified. |
| OPPO | Option 2 is simplest and avoids redundant cancellation. |
| HW/HiSi | Option 3a.  From the UE perspective, it is preferable since the UE can make the cancellation as soon as possible.  For the gNB, if the LP transmission should be cancelled, then it can schedule a HP PUCCH that is overlapping with the LP channel, regardless, if the HP PUCCH is a SR PUCCH, or carries HARQ-A/N for a PDSCH that has been scheduled by a HP DCI, or the HP PUCCH resulted from HARQ-ACK and SR multiplexing (i.e. according to the UE procedure in 9.2.5.1 for multiplexing HARQ-ACK or CSI and SR in a PUCCH in TS38.213). Otherwise if the LP should not be cancelled, the gNB should not let the HP channel overlap with the LP channel. |
| Nokia, NSB | Option 2.  We are also open to discuss Option 2’ by Samsung. |
| Vivo | Option 3a.  gNB can schedule a HP PUCCH which overlapps with the LP channel if it wants to cancel the LP channel. The sufficient cancellation timeline after UE performing overriding and multiplexing procedure can be guaranteed by gNB. |
| **Qualcomm** | Option 3, but with the following change for clarity:   * **Option 3: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:**   **the UE checks overlapping between HP and LP channel ~~for each HP grant~~ before and after each HP grant it receives, including any intermediate HP channel that results from UCI multiplexing and PUCCH overriding triggered by each of the HP grant.** |

**Question #2: If RAN1 agrees to adopt either Option 3 or 3a, do you agree that a reference to Section 9.2.3 of TS 38.213 should be added in the specification to capture the fact that a HP intermediate channel could be a PUCCH carrying HARQ-ACK information overridden by another HP DCI?**

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| **Company** | **Comment** |
| Samsung | Agree for Option 3.  We would like to ask the difference between Option 3 and 3a.  For Option 3, intermediate HP channels during HP PUCCH overriding (HARQ-ACK overriding) are considered for cancelling LP channel.  For Option 3a, intermediate HP channels during HP PUCCH overriding (HARQ-ACK overriding) are not considered for cancelling LP channel.  Is it the correct understanding? If so, the question seems only related to Option 3. |
| HW/HiSi | We prefer not adding it. But if companies think it makes the spec more clear, then it is also fine for us to add the reference to Section 9.2.3.  We have a different view on Option 3a compared to Samsung. In our understanding, HARQ-ACK overriding is the same in Option 3 and 3a. The key difference between Option 3 and 3a is that for the former, the UE needs to perform multiplexing for each DCI, which is not required in Option 3a in our understanding. |
| Nokia, NSB | If Option 2 (or Option 2’) is eventually not supported, then Option 3 (which corresponds to the current specs) should be again the baseline. We would be fine with adding a reference to Section 9.2.3 to clarify that a HP intermediate channel could be a PUCCH carrying HARQ-ACK information overridden by another HP DCI. |
| vivo | We can agree to add a reference to Section 9.2.3.  The difference between option 3 and option 3a is intermediate check number. For option 3, UE will perform intermediate check after each received DCI while UE only perform intermediate checks up to 3 times for option 3a. |
| Qualcomm | We think considering the intermediate PUCCH transmissions was intended and the addition of a reference to Section 9.2.3 is needed in the specification. |

Regarding option #2, let us examine some aspects with a simple example as follows:



In this example, HP DCI1 schedules the HP HARQ-ACK, which itself overlaps with an SR-PUCCH. When multiplexed, SR and HARQ-ACK should be transmitted on the new PUCCH resource which is overlapping with the LP PUSCH. A UE later also receives another HP DCI, HP DCI 2, which schedules the HP PUSCH. The HP PUSCH is overlapping with the intermediate HP PUCCH.

One concern raised by multiple companies regarding the current UE behavior is UE complexity in determining the intermediate channels. However, according to Option 2, the UE still needs to track the HP DCIs sequentially and to determine the intermediate channels accordingly in order to derive the deadline for intra-UE prioritization.

**Question #3: Does option 2 relax the UE complexity by allowing a UE to not determine the intermediate channels sequentially? Does option 2 provide any other relaxation for the UE?**

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| **Company** | **Comment** |
| Samsung | For option 2, without the restriction in option 2’, UE may need to perform overriding/multiplexing whenever receives a DCI.  For option 2’, the overriding/multiplexing implementation can be relaxed. UE can wait until the deadline to perform HARQ-ACK overriding and then multiplexing. UE doesn’t need to perform multiplexing during the HARQ-ACK overriding procedure. |
| **OPPO** | In our understanding, only uplink channel scheduled by DCI is used to derive the deadline for intra-UE prioritization. Intermediate multiplexing is not required.  With respect to above example, the deadline for intra-UE prioritization is determined by earliest starting point of PUCCH for SR, PUCCH for HARQ-ACK. |
| **HW/HiSi** | In our understanding, in option 2 it is required that the UE waits until the deadline, i.e. it has to wait for potential HP DCIs coming later before making a cancellation decision. This complicates the UE implementation. If the UE instead is allowed to make the cancellation decision earlier, e.g. based on HP DCI 1, then it is simple to perform the cancelation of the LP PUSCH from the first symbol. Otherwise the UE might not be able to achieve that.  For the example given above, we share the FL’s view that the UE still needs to determine the intermediate channels to derive the deadline for intra-UE prioritization. |
| **Nokia/NSB** | We would be fine to go with Option 2’ by Samsung that would reduce the UE impact / complexity, as discussed by Samsung above.  Just to note here, it is not just about UE complexity, but also gNB complexity and preventing unnecessary LP UCI / channel dropping in the end. So the main target is not relaxation of UE complexity! |
| vivo | We also think that Option 2 does not relax the UE complexity.  When UE receives a HP DCI, it does not know whether the HP DCI is the final DCI. So, overriding or multiplexing procedure would be performed. If the resulting UL channel overlaps with LP channel. UE can start the cancellation of LP channel.  If it want relax the UE complexity for option 2, a deadline would be required. After the time UE assumes that gNB do not transmit the HP DCI further. |
| Qualcomm | Even under option 2, the UE still needs to track and construct the intermediate channels since the deadline for cancellation is a function of the starting symbol of the intermediate channels too. In that sense, option 2 does not relax the UE’s complexity. |

According to option 2, all HP DCIs must arrive before the earliest symbol of the HP channels, where at least one of them is overlapping with a LP channel. In the example above, HP DCI 1 and HP DCI2 should both arrive before the red line which provides Tproc,2+d1 time for cancellation from the start of the intermediate channel. In case the HP DCI 2 is arrived late, the scheduling of HP PUSCH should be delayed such that the HP PUSCH is not overlapping with the intermediate HP channel.

**Question #4: Do you agree that Option 2 potentially increases the scheduling latency of URLLC transmissions? If not, please provide your reasoning in the table below.**

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| **Company** | **Comment** |
| Samsung | Agree. But the latency issue can be avoided by proper scheduling. For example, short PUCCH duration. |
| OPPO | Not sure. Firstly, the deadline for DCI scheduling overlapped uplink channel is put forward by d1, up to 2 symbols. Considering search space periodicity is not very small and traffic arrival possibility in short gap is very small, the real latency is very margin. Secondly, proper scheduling can avoid latency increase further. |
| HW/HiSi | We agree that Option 2 increases the latency of URLLC transmissions.  Please also note that DCIs scheduling HP PUSCH(s) in other cells also need to fulfill the deadline and should come before the red-line in the example given above. |
| Nokia/NSB | Agree that this may increase the scheduling latency, but then at the same time for certain cases it prevents unnecessary UCI / LP channel dropping. |
| vivo | We agree that Option 2 potentially increases the scheduling latency. |
| Qualcomm | Yes. If a HP packet arrives late and if its scheduling DCI cannot be sent before the deadline, the HP packet should be scheduled at a later time. |

With the currently specified UE behavior, a UE can cancel the LP channel from the time of HP DCI decoding until the start of the first overlapping channel. Under Option 2, on the other hand, the UE has to wait until the cancellation deadline before it can launch the cancellation procedures.

**Question #5: Do you agree that the currently specified UE behavior gives more flexibility to UE in terms of deciding the timing of LP channel cancellation? If not, please provide your reasoning.**

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| **Company** | **Comment** |
| Samsung | Agree. But we don’t think the flexibility is as important as complexity. The intention of the discussion is to reduce implementation complexity for both UE and gNB. |
| OPPO | Any option has the same flexibility as currently specified UE behavior if complexity is not considered. To be specific, for option 2, UE can make decision on cancellation before cancellation deadline (Maybe updated in later). But is it necessary? There is no benefit, why does UE apply complex procedure. |
| HW/HiSi | Yes |
| Nokia/NSB | Agree, but as stated in our response also to Questions #3 and #4, it is not just about UE complexity and flexibility, but also performance of the overall scheme. And there any unnecessary LP UCI/channel dropping is of advantage. |
| vivo | Agree |
| **Qualcomm** | Yes. Under Option 2, the UE is required to wait until the cancellation deadline before it can initiate cancellation procedures. This, in turn, makes UE implementation more complicated. |

## 2.2 A summary of the First Round of Discussions

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# 3 Second Round of Discussions

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## 3.2 A Summary of the Second Round of Discussions

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# 4 References

**[1] R1-2106673, “UE procedures for UCI multiplexing and prioritization,” Ericsson**

**[2] R1-2106825, “Correction on UE procedure for intra-UE prioritization/multiplexing,” Nokia, NSB**

**[3] R1-2107270, “Draft CR on scheduling and HARQ,” OPPO**

**[4] R1-2107271, “Discussion on scheduling and HARQ,” OPPO**

**[5] R1-2107557, “Discussion on Nokia draft CRs on Rel-16 URLLC/IIoT scheduling/HARQ and SPS enhancements,” Nokia, NSB**

**[6] R1-2107715, “Remaining issues on intra-UE multiplexing/prioritization for eURLLC,” Apple Inc.**

**[7] R1-2107715, “Remaining issues on intra-UE multiplexing/prioritization for eURLLC,” vivo**

# 5 Appendix: Summary of Proposals

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| **Ericsson: R1-2106672**  Step 2 in the *Working assumption* (copied below), requires that the cancellation should be performed “before performing multiplexing/overriding HP channels”.   1. *A UE cancels the transmission of a LP channel including any intermediate scheduled LP transmission that does not overlap with any LP channel, if any DCI schedules an overlapping HP transmission with the LP channel, before performing multiplexing/overriding HP channels if any.*     The requirement in Step 2 of WA to perform cancellation “before” overriding/multiplexing, is in contradiction with the principle of operation based on fulfilling timeline requirements that limits the implementation flexibility and results in unexpected outcomes.  The requirement in Step 2 of WA to perform cancellation “before” overriding/multiplexing, can lead the UE to perform unnecessary cancellation operations without clear motivation.   1. Confirm the WA without performing the intermediate cancellation in Step 2 while keeping the corresponding cancelation timeline requirements. 2. Adopt TP1 for Clause 9 in 38.213 or equivalently the accompanying draft CR   ====================== START of Text Proposal 1 for TS38.213 ========================== 9 UE procedure for reporting control information \*\*\*Unchanged text is omitted\*\*\*  When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of larger and/or smaller priority index, the UE resolves the overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of each priority index as described in clause 9.2.5 and 9.2.6 before resolving the overlapping for PUCCH transmissions without SL HARQ-ACK or the overlapping for PUCCH transmissions and PUSCH transmissions.  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports before considering limitations for UE transmission as described in clause 11.1, including repetitions if any, the UE first resolves the overlapping for PUCCH and/or PUSCH transmissions of ~~smaller~~ a same priority index as described in clauses 9.2.5 and 9.2.6. Then,  - if a transmission of a first PUCCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of a transmission of a second PUSCH or a second PUCCH of smaller priority index, the UE cancels the repetition of a transmission of the second PUSCH or the second PUCCH before the first symbol that would overlap with the first PUCCH transmission  - if a transmission of a first PUSCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of the transmission of a second PUCCH of smaller priority index, the UE cancels the repetition of the transmission of the second PUCCH before the first symbol that would overlap with the first PUSCH transmission  where  - ~~the overlapping is applicable~~ the UE expects that the transmission of a larger priority index PUCCH or PUSCH scheduled by a DCI in a PDCCH reception that would overlap in time with a transmission of a smaller priority index PUSCH/PUCCH or a PUCCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception before or after resolving overlapping among channels of larger priority index, if any, as described in clauses 9.2.5 and 9.2.6  - any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in clause 11.1  ~~- the UE expects that the transmission of the first PUCCH or the first PUSCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception~~  - is the PUSCH preparation time for a corresponding UE processing capability assuming [6, TS 38.214], based on and as subsequently defined in this clause, and is determined by a reported UE capability  \*\*\*Unchanged text is omitted\*\*\*  ===================== END of Text Proposal 1 for TS38.213 ========================== |

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| **Nokia, NSB, R1-2106825**  ====================== START of Text Proposal 1 for TS38.213 ========================== 9 UE procedure for reporting control information \*\*\*Unchanged text is omitted\*\*\*  When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of larger and/or smaller priority index, the UE resolves the overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of each priority index as described in clause 9.2.5 and 9.2.6 before resolving the overlapping for PUCCH transmissions without SL HARQ-ACK or the overlapping for PUCCH transmissions and PUSCH transmissions.  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports before considering limitations for UE transmission as described in clause 11.1, including repetitions if any, the UE first resolves the overlapping for PUCCH and/or PUSCH transmissions of ~~smaller~~ a same priority index as described in clauses 9.2.5 and 9.2.6. Then,  - if a transmission of a first PUCCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of a transmission of a second PUSCH or a second PUCCH of smaller priority index, the UE cancels the repetition of a transmission of the second PUSCH or the second PUCCH before the first symbol that would overlap with the first PUCCH transmission  - if a transmission of a first PUSCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of the transmission of a second PUCCH of smaller priority index, the UE cancels the repetition of the transmission of the second PUCCH before the first symbol that would overlap with the first PUSCH transmission  where  - ~~the overlapping is applicable~~ the UE expects that the transmission of a larger priority index PUCCH or PUSCH scheduled by a DCI in a PDCCH reception that would overlap in time with a transmission of a smaller priority index PUSCH/PUCCH or a PUCCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception before or after resolving overlapping among channels of larger priority index, if any, as described in clauses 9.2.5 and 9.2.6  - any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in clause 11.1  ~~- the UE expects that the transmission of the first PUCCH or the first PUSCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception~~  - is the PUSCH preparation time for a corresponding UE processing capability assuming [6, TS 38.214], based on and as subsequently defined in this clause, and is determined by a reported UE capability  \*\*\*Unchanged text is omitted\*\*\*  ===================== END of Text Proposal 1 for TS38.213 ========================== |

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| **OPPO, R1-2107270**  ====================== START of Text Proposal 1 for TS38.213 ========================== 9 UE procedure for reporting control information \*\*\*Unchanged text is omitted\*\*\*  When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of larger and/or smaller priority index, the UE resolves the overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of each priority index as described in clause 9.2.5 and 9.2.6 before resolving the overlapping for PUCCH transmissions without SL HARQ-ACK or the overlapping for PUCCH transmissions and PUSCH transmissions.  When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes other than PUCCH transmissions with SL HARQ-ACK reports before considering limitations for UE transmission as described in clause 11.1, including repetitions if any, the UE first resolves the overlapping for PUCCH and/or PUSCH transmissions of ~~smaller~~ a same priority index as described in clauses 9.2.5 and 9.2.6. Then,  - if a transmission of a first PUCCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of a transmission of a second PUSCH or a second PUCCH of smaller priority index, the UE cancels the repetition of a transmission of the second PUSCH or the second PUCCH before the first symbol that would overlap with the first PUCCH transmission  - if a transmission of a first PUSCH of larger priority index ~~scheduled by~~ corresponding to a DCI format in a PDCCH reception would overlap in time with a repetition of the transmission of a second PUCCH of smaller priority index, the UE cancels the repetition of the transmission of the second PUCCH before the first symbol that would overlap with the first PUSCH transmission  where  - ~~the overlapping is applicable~~ the UE expects that the transmission of a larger priority index PUCCH or PUSCH scheduled by a DCI in a PDCCH reception that would overlap in time with a transmission of a smaller priority index PUSCH/PUCCH or a PUCCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception before or after resolving overlapping among channels of larger priority index, if any, as described in clauses 9.2.5 and 9.2.6  - any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission as described in clause 11.1  ~~- the UE expects that the transmission of the first PUCCH or the first PUSCH, respectively, would not start before after a last symbol of the corresponding PDCCH reception~~  - is the PUSCH preparation time for a corresponding UE processing capability assuming [6, TS 38.214], based on and as subsequently defined in this clause, and is determined by a reported UE capability  \*\*\*Unchanged text is omitted\*\*\*  ===================== END of Text Proposal 1 for TS38.213 ========================== |

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| **OPPO, R1-2107271**  **Observation 1:** In most cases, multiplexing determination is before prioritization.   * Even the multiplexing timeline ending is after prioritization timeline ending, the whole picture of multiplexing channel almost remains the same before and after prioritization timeline ending.   **Observation 2:** Scheduling restriction from option 2 is very limited, even can be ignored.  **Proposal 2: Option 2 is preferred.** |

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| **Nokia, NSB, R1-2107557**  **Proposal 2.1:** To clarify the UE procedure for intra-UE prioritization/multiplexing regarding intermediate checking, adopt the following option:   * Option 2: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.   + Any HP channel that overrides or overlaps with a HP channel that overlaps with a LP channel shall meet the cancellation timeline, namely all HP DCIs must arrive *Tproc,2+d1* before the earliest symbol that would be cancelled by the ~~final~~ HP channel.   + All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels. |

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| **Apple, R1-2107715**  **Proposal 1:** Adopt Option 2 with minor clarification as below:   * Option 2: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.   + Any scheduled HP channel that overrides or overlaps with a HP channel that overlaps with a LP channel shall meet the cancellation timeline, namely ~~all~~ the corresponding HP DCI~~s~~ must arrive *Tproc,2+d1* before the earliest symbol that would be cancelled by the ~~final~~ HP channel.   + All HP PUCCH/PUSCH channels except the final HP PUCCH/PUSCH that gets transmitted by the UE are intermediate channels. |

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| **Vivo, R1-2107982**  ***Proposal 1：For intra-UE prioritization procedure, option 3a is preferred***   * **Option 3a: [No change from the spec is needed.] Clarify that the “before or after” term in Claus 9 in 38.213 is interpreted as:**    + ***A UE checks the overlap between a HP channel and a low priority channel before multiplexing. If there is an overlap, the LP channel gets cancelled. If not, a UE performs multiplexing across the HP PUCCH channels. If then there is an overlap with a LP channel, the LP channel gets cancelled. Then, multiplexing between PUCCH and PUSCH is performed. If then there is an overlap with a LP channel, the LP channel gets cancelled.*** |