**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.**

**[FL] In the first added sub-bulltet, is PUSCH missing?** **[Samsung]** In our understanding, a DG PUSCH is always a final channel. If UE receives a HP UL grant, the collision LP channels needs to be canceled. If UE receives a HP UL grant UE needs check whether the HP PUSCH overlaps with HP PUCCH, therefore UE needs to perform HP HARQ-ACK overriding and HP PUCCH multiplexing if any. If the result HP PUCCH does not overlap with the HP PUSCH, UE doesn’t need to use the result PUCCH to cancel LP channels immediately. Instead, UE can wait until the deadline of HP HARQ-ACK overriding.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.**  |
| **Intel** | Option 3. To the modification from QC, it is not clear what it means to “check … before … each HP grant it receives” – how to determine the time “before reception of a HP grant”? In this regard, the original text clarification per Option 3 seems sufficiently clear.[FL] Thanks for the question. The modification is to state that before each “new” grant, the UE determines the channel on which it has to transmit and then update it based on the reception of the new grant.  |
| **DOCOMO** | Option 3. |
| **Apple** | Option 2It does not mandate the UE to always perform intermediate multiplexing, and the cancellation is only done based on the final HP transmission, which avoids unnecessary cancellation.We would be also be fine with Option 4. |
| **Ericsson** | Option 2´(Or at least we think our updated Proposal is aligned with Samsung description).We understood from last meeting that there was a concern about timeline. On the other hand. The act of intermediate cancelation creartes additional UE complexity and ambiguity. Therefore, we thought let’s just remove intermediate cancellation, but not change the timeline. Hopefully that addresses all the concern. If I am not mistaken at this hour, it should be aligned with Samsung. |

**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.  |
| Intel | Agree. |
| DOCOMO | Agree |
| Apple | If we understand correctly, the intention of Option 3a is not to consider any PUCCH for HARQ-ACK overridden by other DCI. But we think this option has timeline issue as explained in our contribution R1-2107715. |
| Ericsson | I hope RAN1 does not agree to Option 3(3a 😊 As we analyzed in the contribution, the source of problem is not the spec, or its clarity, etc. Therefore, with Option 3/3a the problem still remains.  |

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. |
| Intel | Agree; Option 2 still requires UE to track all intermediate channels; just that the final cancelation is limited to final HP channel (which, as vivo mentioned, the UE doesn’t know until the deadline). On the other hand, Option 3, as currently specified, allows the UE to process things as they come, and the complexity increase for Option 3 as against Option 2 (or even Option 2’) is not obvious since sufficient processing times are available at the UE for each of the constituent steps. |
| DOCOMO | In our understanding, Option 2 does not relax the UE complexity. UE still needs to check HP DCIs as it does not know which HP DCI is the last one.  |
| Apple | Here is what we try to explain in our contribution R1-2107715 regarding Option 2:“For Option 2, the intention is that the gNB/UE are not mandated to perform intermediate multiplexing after receiving each UL DCI. With the timeline in place, one example of how the UE can implement is as follows:1. The LP channels are processed in the same way as in Rel-15.
2. The UE performs the multiplexing for HP channels at d1 symbols before the regular HP channel freezing time and checks if any of the HP channels after multiplexing would cancel the LP transmission. If yes, the UE cancels the LP transmission.
	* The additional timeline constraint introduced in Option 2 guarantees that if the UE cancels a LP transmission in this step, there will not be another HP DCI that comes later.
	* If HP cancelling LP occurs in this step, the UE does not need to continue with step 3, because the HP transmission is already final in this case.
	* This is considered as an extra multiplexing step that the UE needs to perform comparing to Rel-15 procedure. However, this step is due to the different cancellation timeline compared to multiplexing timeline, so it is a step that exists in any of the options, not unique to Option 2. (Different UE implementation may perform this step at different time.)
3. If in step 2 the UE does not have any HP cancelling LP, the UE continues to process and transmit the HP channels in the same way as in Rel-15.

Note that there should not be overlapping HP and LP as the outcome of this step, because any overlapping should have been identified in step 2 already.”The bottom line is that with Option 2, the UE is not required to do intermediate multiplexing after receiving **EACH** DCI. It could be true that the UE may still need to do certain intermediate multiplexing, but exactly when/what intermediate multiplexing is done is completely UE implementation as long as the final outcome is the same. Option 2 does not require the UE to change the existing R15 implementation. Note that the UE can also choose to do intermediate multiplexing after receiving each DCI. So it is totally up to UE implementation.In the example, of course the UE needs to do SR+HARQ-ACK multiplexing first, and then multiplex UCI on PUSCH, but this is business as usual.Maybe a different/simple example to show why Option 2 has no/less constraint on UE implementation: in the example below, HP DCI1 comes much earlier and HP DCI2 comes later and satisfies the cancellation timeline. In this case, there is no need for the UE to do intermediate multiplexing after receiving HP DCI1. |

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| Ericsson | Agree with Samsung. That’s why we updated our proposal to relax the UE and do the operation any time it want, e.g. until the timeline without resulting in ambiguity for NW.  |

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.  |
| Intel | Agree, and this is a more serious shortcoming compared to the claimed complexity reduction from Option 2. |
| DOCOMO | We agree that Option 2 increases the latency. |
| Apple | We acknowledge that there may be minor impact on scheduling delay in certain cases, but the difference is only up to d1 symbols. For overlapping channels, they already need to satisfy the Tproc,2 multiplexing timeline, and the cancellation timeline is Tproc,2+d1 symbols. If we can accept the regular cancellation timeline is d1 symbols more, it should be also acceptable to have d1 more symbols in the example case. |
| Ericsson | We are a bit confused with this discussion. I hope in next round, instead, or in addition to Option 2, we discuss Option 2´ or our proposal that changes no timeline and just remove intermediate cancellation. Then, none of these issues would remain. |

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.**[FL] Being able to cancel the LP channel just upon decoding DCI vs. waiting for some time before the action can be launched, while still performing other processing for LP channel, reduces UE complexity.** **[Samsung2] Agree with FL for some implementation. For some other implementation it may not.****For PUCCH determination, UE needs to first determine a PUCCH for HARQ-ACK, then run the pseudo code in 9.2.5 to determine non-overlapping PUCCHs. It could be simpler if UE can wait to a deadline to first perform HARQ-ACK overriding and then PUCCH multiplexing to avoid performing intermediate PUCCH multiplexing during the procedure of HARQ-ACK overriding.** |
| 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. |
| **Intel** | Agree, and the same idea is expressed in our answers in response to Question #3. |
| **DOCOMO** | Agree |
| **Apple** | We tend to disagree how the question is asked. ☺The flexibility of when the UE can cancel LP is not important in our view, because the UE would need to perform the final HP multiplexing in any case and need to be able to check against and cancel LP channel in that stage. Maybe with Option 3, the UE could initiate LP cancellation earlier, but we don’t see why this is important. The cancellation timeline is in place already to make sure cancellation is possible and UE needs to support it.**[FL] Please refer to my response above to Samsung.** What is more important in our view is:1. avoid unnecessary cancellation. All the cancellation due to intermediate channels only is unnecessary.
2. We do not want the procedure to be defined in a way that the R15 UE implementation of multiplexing may need to be changed. It should be left to UE implementation on whether to perform intermediate multiplexing after receiving each DCI. On the other hand, cancellation is a new procedure in R16, and UE can accommodate different implementation options much easier.
 |
| **Ericsson** | Please see previous comments.Also, it would be appreciated if the issues with current spec were also analyzed with some questions. Hopefully, that can be improved in the next round.  |

## 2.2 A summary of the First Round of Discussions

* Based on the comments in the first round, the current status is as follows:
	+ **Option 2:** OPPO, Nokia, Apple
	+ **Option 2’:** Samsung, [Nokia], [Ericsson]
	+ **Option 3:** Qualcomm, Intel, DOCOMO
	+ **Option 3a:** Huawei/HiSi, vivo
	+ **Option 4:** Qualcomm, Apple
* Companies agree to add a reference to Section 9.2.3 of TS 38.213 if the current specification is to be kept.
* On the question about whether Option 2 can relax the UE implementation complexity, the companies’ positions are as follows:
	+ **It does not:** Samsung, Huawei/HiSi, vivo, Qualcomm, Intel, DoCoMo, Ericsson
	+ **It does:** OPPO, Apple
* On the additional latency introduced by Option 2, the companies responded as follows:
	+ **Option 2 increases latency:** HW/HiSi, Nokia/NSB, vivo, QC, Intel, DCM
	+ **The increase in the latency is not an issue:** OPPO, Samsung, Apple
* On whether Option 3 (based on the current specification) provides a UE with more implementation flexibility than Option 2, the companies’ positions are as follows:
	+ **Yes:** HW/HiSi, Nokia, vivo, QC, Intel, DCM
	+ **Yes, but it does not translate into complexity reduction:** Samsung, OPPO, Apple
	+ **No: --**

# 3 Second Round of Discussions

Given the discussions so far, the feature lead proposal is to not consider Option 2 any further. Option 2 (and this entire discussion) was brought up as a way to reduce the UE complexity as compared to the current specification. Based on the responses, it does not help reducing the UE complexity.

Option 4 is only supported by two companies; some companies have already raised concerns about this option in the previous meeting. Hence, the recommendation is to not pursue it in the discussions anymore.

Regarding Option 3a, let us consider the example illustrated in the figure below by focusing on PUCCH #5 and #6 and their associated DCIs. Based on Option 3a, the UE checks the overlap between PUCCH #1, #2 and #4 and the LP channel individually. Then, it checks the overlap between PUCCH #6 and the LP channel. Finally, it checks the overlap between PUSCH #3 and the LP channel.

Now, assume that the UE receives the HP DCI #1 first and its SR state is positive. So far, the UE has to transmit UCI on PUCCH #5. The UE then waits longer to determine whether there are other DCIs. If DCI #2 is received, then the UE has sufficient time to cancel the LP channel. If the UE does not receive DCI #2, since it has already waited, it will have less time for cancellation.



Regarding Option 3 some companies mentioned that it could lead to unnecessary cancellation of the LP channels.

To continue the discussions, please respond to the following questions:

**Question #1: Based on the discussions so far, the feature lead recommendation is to not pursue Option 2 and 4. If you have a strong objection, please comment in the table below.**

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| **Company** | **Comment** |
| Apple | We do not think Option 2 should be excluded at this stage because we do not see a solution to address our concern yet. We are still trying to understand the other options. If there is an option that can address our concern, we may be fine to drop Option 2 then.We are fine to exclude Option 4.I would like to make **further clarification on Option 2**: the point is not exactly about whether UE complexity is reduced or not. If the UE is already doing multiplexing after receiving each DCI, of course the complexity is not reduced.The points are:(1) it does not require the UE to change how multiplexing is already implemented. In R15, the UE has the flexibility to choose when to perform the multiplexing. Doing it after receiving each DCI is of course one implementation choice, but it can also be implemented in different ways. R16 is built on top of R15, and it should not mandate UE to change the existing implementation for multiplexing unless absolutely necessary. At this point, we do not think it is absolutely necessary. In fact, Option 3 causes more unnecessary cancellation, so it is not very well justified.(2) As mentioned above, it avoids unnecessary cancellation by the intermediate channels. |
|  |  |

**Question #2: Based on the discussions in this section, Option 3a has cancellation timing issues, i.e., it may not leave sufficient time for the UE to perform cancellation. Do you agree? If you do not, please provide your reasoning.**

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| --- | --- |
| **Company** | **Comment** |
| HW/HiSi | We don’t agree that there are cancellation timing issues for option 3a and explain our understanding below. It would be great to hear the views from other, if we have missed something here: For the multiplexing and overriding case shown by the moderator above, please note that there also has to be a multiplexing timeline for the HP channels. In the example figure above, if the UE does not receive DCI #2, then it will wait until the deadline of the multiplexing timeline. In our understanding, this will not reduce the cancellation timeline, because the multiplexing timeline is relaxed compared to the cancellation timeline. [Apple] the multiplexing timeline is not always relaxed compared to cancellation timeline. Please see our comments for vivo below.@Apple: The multiplexing timeline is defined between the PDSCH and PUCCH, but the cancellation time-line between the DCI and the PUCCH. Considering the different reference points we think the multiplexing time-line is more relaxed.For HARQ-ACK overriding as shown in the example below, option 3a and option 3 are the same, i.e. each HP HARQ-ACK PUCCH (PUCCH 1 and PUCCH 2) would cancel the LP PUCCH. Figure 2: Case 2 overriding only[Apple] Please see our comments below where we show a problematic case.The only difference between option 3 and option 3a is that option 3 requires the UE to do the multiplexing for each DCI, whereas option 3a does not require that. For the example figure from the moderator above, Option 3 would cancel the LP channel due to PUCCH #5. In Option 3a, there would not be an overlapping check after PUCCH #5, and only PUCCH #6 would be checked for a potential overlap with LP.[Apple] Also, if you think there is no timeline issue, why do we need to check HP channels before multiplexing? Should not final HP PUCCH/PUSCH be sufficient already?@Apple: The reason is that multiplexing might not always occur, there is for example no multiplexing time-line without the existence of HP SR |
| Vivo | We also think there are no timeline issues for option 3a.The multiplexing timeline needs at least satisfy while cancellation timeline requires . Therefore, timeline issue can be avoided by gNB scheduling.[Apple] The multiplexing timeline can be smaller than the cancellation timeline (e.g. when d\_2,1 = 0 and d\_1 = 2), correct? @Apple: In our opinion, the issue caused by at most one symbol difference between MUX and cancellation timeline can be easily avoided by gNB scheduling. On the other hand, gNB can schedule a HP PUCCH before multiplexing, which overlaps with LP channel if it wants to cancel a LP channel. The sufficient cancellation time can be guaranteed by gNB.[Apple] If the suggestion here is that the gNB schedules the DCI earlier enough to satisfy the cancellation timeline, then additional timeline condition would need to be introduced. This seems to be the same as Option 2? @Apple: The example here explains that UE can start the cancellation of LP channel earlier by gNB implementation. It needn’t the additional timeline. On the contrary, option 2 requires the cancellation only starts from Tproc,2+d1 before the earliest overlapping symbol, which is against the current cancellation timeline. |
| Apple | Reading the comments from Huawei/HiSi/vivo, I agree that in some cases there is no timeline issue, especially if the final HP channel cancel the LP (in which case cancellation timeline is always in place).The issue exists when the intermediate HP overlaps with the LP but the final HP does not overlap with LP. As we explain in our contribution R1-2107715, for the example below, HP DCI1 schedules a HP PUCCH1 that overlaps with LP PUCCH. If there is no more DCI coming, LP PUCCH should be cancelled. But if HP DCI2 comes which schedules HP PUCCH2 not overlapping with LP PUCCH, LP PUCCH should not cancelled according to Option 3a. However, the UE can only know that there will not be any further overriding at N3. But if the UE finds there is no overriding at this point, it is too late for UE to initiate the cancellation of LP PUCCH. Please check and see if I miss anything or misunderstand Option 3a.Diagram, timeline  Description automatically generated[HW/HiSi] For your example above, our understanding of Option 3a is that the LP PUCCH would be cancelled by the HP PUCCH 1, regardless if the gNB sends HP DCI 2 or not. This is because the UE cannot wait for the HP DCI 2 to make its cancellation decision. If our understanding is correct, then Option 3 and 3a are the same in this figure. The only difference between Option 3 and 3a is whether or not the UE needs to perform HARQ-ACK and SR multiplexing for each received DCI. |
| Qualcomm | We do agree that Option 3a introduces additional processing timing complications at the UE. This is illustrated both via an example before this question and via the scenario shown by Apple.  |
| DOCOMO | We agree that Option 3a has cancellation timeline issue when final PUCCH does not overlap with LP PUCCH but intermediate one does. |
| Samsung | If multiplexing timeline is not smaller than the cancellation timeline, no such issue. |
| ZTE | To align my understanding, may I provide 3 figures. If I understand wrong, please correct me. Figure aQ1 is the latest timeline to determine whether HP PUCCH1 would cancel LP PUCCH/PUSCH and Q3 is the overriding timeline. UE will wait until the latest timeline to determine whether HP PUCCH1 would cancel LP PUCCH/PUSCH, at least LP channel can partially transmit. In the figure a, HP DCI2 is received before the latest timeline, and if UE decides overriding immediately after DCI2, HP PUCCH1 will be overridden by HP PUCCH2, then LP PUCCH/PUSCH will be completely transmitted.If the HP DCI2 is moved between the Q1 and Q3, HP PUCCH1 will be overridden by HP PUCCH2, but LP PUCCH/PUSCH will NOT be transmitted as the cancellation timeline is passed.Obviously, if the DCI2 is moved after Q3, it is an error case as the overriding timeline is not satisfied.Figure b1In figure b1, HP PUSCH replaces the last PUCCH and the multiplexing timeline replaces the overriding timeline. The HP DCI2 is received before the latest timeline, HP PUCCH1 will be multiplexed with HP PUSCH if immediately multiplexing after the DCI2 and before Q1, and then LP PUCCH/PUSCH can be transmitted. If the UE determines multiplexing after the Q1, anyway LP channel is cancelled. The discretion of UE multiplexing will cause two consequences for LP channel.If DCI2 is moved between Q1 and Q2, HP PUCCH1 is multiplexed with HP PUSCH, but LP channel is still cancelled. Obviously, if the DCI2 is moved after Q2, it is an error case.Figure b2In figure b2, Q2 is before Q1, this is the difference with b1. The DCI2 is received before Q2, and Q2 is advanced than Q1, HP PUCCH1 is multiplexed with HP PUSCH and LP channel need not be cancelled.The DCI2 after Q2 is an error case.Conclusion: from the three cases, the latest timeline (deadline) is important to determine the procedure of multiplexing/overriding/cancellation if we do not allow the intermediate HP channel to cancel the LP channel.  |

**Question #3: Option 2’ could increase the scheduling latency for URLLC as it puts a restriction on when a HP channel can be scheduled. Option 3 could lead to cancelling a LP channel that could have been transmitted if the UE had waited longer. Do you agree with this characterization? If so, which of the two aspects you think is more important: (1) protecting the LP channels, or (2) ensuring low latency for URLLC?**

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| **Company** | **Comment** |
| Apple | Option 2’ has some additional scheduling constraint for HARQ-ACK overriding. Practically we don’t think this is an issue. Since all the DCIs schedule HP channel, it makes sense for the gNB to schedule PUCCH earlier even for the earlier DL DCI. The constraint that later scheduled PUCCH should not start earlier than the earlier scheduled PUCCH should be fine.However, our issue with Option 2’ is we think there is still timeline issue.One example is the same example as what we have for Option 3a above (under Question#2). Please check.[Samsung] We agree the issue might happen for Option 2’ and we suggest to add a similar restriction as Option 2 but only for PUCCH below.**Updated Option 2’*** **Option 2’: The UE does not use the outcome of intermediate multiplexing for HP channels to cancel LP channels.**
	+ **Any HP PUCCH ~~channel~~ that overrides ~~or overlaps~~ ~~with~~ a HP PUCCH ~~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 PUCCH ~~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.**

Another example is the one brought up by QC that triggered all the discussions some meetings back. Here if the UE does the cancellation based on the final PUCCH/PUSCH, the UE should not cancel LP PUSCH in this case. However, if the HP UL grant does not come, the UE should cancel LP PUSCH. If the UE waits until it is certain that there is no more DCI coming, it can be too late for the UE to cancel LP PUSCH. [Samsung] We have different understanding on this case and would like to clarify a bit. In short, T2 should be before T1 as shown above, otherwise the multiplexing timeline is not satisfied.The deadline of overriding is N3 before the starting of HP PUCCH in the figure above. If *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for the serving cell with the second DCI format and for all serving cells with corresponding HARQ-ACK information multiplexed in the PUCCH transmission in the slot, for ,  for ,  for ; otherwise ,  for ,  for ,  for ,  for .The deadline of multiplexing HP PUSCH and HP PUCCH is before the starting of HP PUCCH where is given by maximum of where for the i-th PUSCH which is in the group of overlapping PUCCHs and PUSCHs, . |
| Qualcomm | We do agree that Option 2’ introduces additional scheduling latency for URLLC which should be avoided. In terms of the cancellation of the LP channels under Option 3, we do not think that it is an issue. At some point of time, a gNB had decided that the LP channel is not important and can be dropped. A gNB would not schedule another HP channel just to resolve the collision and to protect the LP channel. If the network thinks that the LP channel is important, it can avoid the collision from the beginning.  |
| DOCOMO | We agree that Option 2’ introduces scheduling latency as later HP PUCCH needs to be ensured that it is later than early scheduled HP PUCCH. Regarding the cancellation of LP channels by Option3, we share the similar view with Qualcomm that think it is not that an issue. |
| Samsung | We agree Option 2’ has some additional scheduling constraint for HARQ-ACK overriding. We share similar view as Apple, we don’t think this is an issue.Regarding the latency, we don’t agree. It can be avoided by proper scheduling. For example, if the first HARQ-ACK PUCCH is scheduled in the first available UL symbol (e.g., symbol 0) in the slot/sub-slot, there won’t be any latency issue for HARQ-ACK overriding. Agree with the analysis of Option 3. |

**Question #4: The following proposal is made in [1]:**

**Confirm the following WA without performing the intermediate cancellation in Step 2 while keeping the corresponding cancellation timeline requirements:**

***Working assumption*** *(RAN1#102-e)*

1. ***Multiplexing/overriding/etc. is performed similar to Rel.15 as if HP channels do not exist; this means that LP operations, multiplexing/overriding/etc., are performed before cancellation.***
2. ***~~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.~~***
3. ***Multiplexing/overriding of HP channels is performed as if LP channels do not exist.***
4. ***A final HP channel is prioritized if it overlaps with a final LP channel, after performing multiplexing of HP channels***

**Please share your views on this proposal in the table below.**

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| **Company** | **Support/No support** | **Comments** |
| **Nokia/NSB** |  | Question for clarification: Is this basically Option 2 / Option 2’ without its first paragraph, i.e. no restrictions on processing timeline (from Option 2) or related scheduling restrictions (from Option 2’? |
| **HW/HiSi** |  | Similar question as Nokia: to which of the discussed options does this WA relate to?In our view there is a dependency between the options we can select and the WA. Maybe it is better to firstly agree on the options before discussing the WA or making spec changes? What do you think? |
| **vivo** |  | One question for this WA: Does only HP channel after multiplexing/overriding operation are considered for the cancellation of LP channels? |
| **Apple** |  | We have similar concern on this one as Option 2’/3a. It removes all the intermediate steps (which is what we like), but without addressing the potential timeline issue. Please see the example cases we provided above on Option 2’ and 3a. |
| **Qualcomm** |  | We do have some questions on this option for Ericsson:1. In the figure above, the Tc timelines are drawn with respect to the beginning of the HP channels, and not the first overlapping channels. Was this intended or is a typo?
2. Let us assume that there is an SR PUCCH overlapping with the HP PUCCH1. Is it guaranteed that the cancellation timeline is satisfied for the new resource which should carry SR and the content of the HP PUCCH1? To be more generic, under this proposal, is the assumption that the cancellation timeline is guaranteed for every possible intermediate channel?
3. It was mentioned that this option removes the unnecessary cancellation of the LP channels. As an example, let us consider the above figure, but assume that PUCCH4 does not exist and let us also move PUCCH3 to the right such that is does not overlap with the PUSCH anymore. In such a case, it seems to us from the figure that the cancellation deadline is reached before the overriding timeline. Hence, before the UE would decide that the final PUCCH is PUCCH3, it can cancel the LP channel. Later, when performing overriding, it determines that the final PUCCH is, in fact, PUCCH3 which is not overlapping with the LP PUSCH. Do you agree?
4. Let us now consider the following example:

 Based on your proposal, the UE cancels the LP channel right at the T\_cancellation deadline. Is it then still possible to schedule a HP PUSCH after this deadline, but before the multiplexing deadline? We would like to understand whether this option would put any restriction on the URLLC scheduling.  |
| **Samsung** |  | We agree with the intention, we prefer Option 2’ to solve this issue. |
| **ZTE** |  | No strong view, slightly prefer option 2’ |

## 3.2 A Summary of the Second Round of Discussions

TBD

# 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 transmissionwhere - ~~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 transmissionwhere - ~~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 transmissionwhere - ~~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.***
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