3GPP TSG RAN WG1 #102-e R1-200xxxx

e-Meeting, August 17th – 28th, 2020

Source: Moderator (OPPO)

Title: Summary#1 of email thread [103-e-NR-IIOT\_URLLC\_enh-04]

Agenda Item: 8.3.3

Document for: Discussion and Decision

# Introduction

This is the summary for the following email discussion:

[103-e-NR-IIoT-URLLC-04] Email discussion/approval for intra-UE multiplexing/prioritization– Jia (OPPO)

* 1st check point: 11/5
* 2nd check point: 11/10
* 3rd check point: 11/12

# Multiplexing UCIs of different priorities in a PUCCH

## Agreements in previous meetings

Agreements:

*Support multiplexing for following scenarios in R17:*

* *Multiplexing a high-priority HARQ-ACK and a low-priority HARQ-ACK into a PUCCH in R17.*
* *Multiplexing a low-priority HARQ-ACK and a high-priority SR into a PUCCH for some HARQ-ACK/SR PF combinations (FFS applicable combinations).*
* *Multiplexing a low-priority HARQ-ACK, a high-priority HARQ-ACK and a high-priority SR into a PUCCH.*

*For the above multiplexing scenarios,*

* *FFS conditions, if needed, for the multiplexing, e.g*
  + *Whether to support multiplexing between different resources not confined within a sub-slot.*
  + *Whether to support multiplexing in case a PUCCH overlaps with more than one PUCCH.*
  + *Timeline requirements.*
* *FFS: details, if needed, of the multiplexing scheme, e.g.*
  + *How to minimize impact on the latency for high-priority HARQ-ACK.*
  + *How to determine the PUCCH resource used for multiplexing (e.g. HP or LP PUCCH resource, or a dedicated PUCCH resource for the multiplexing).*
  + *How to multiplex the HARQ-ACK bits (e.g. multiplexing, bundling).*
  + *How to encode the UCIs with different priorities (e.g. separate coding vs. joint coding)*
  + *How to guarantee the target code rate (e.g. payload control, multiplexing priority, LP HARQ-ACK compression/compaction).*
  + *Explicit indication for enabling multiplexing.*

*Multiplexing rule and order (e.g. HP/LP multiplexing is after resolving collision within the same priority).*

## Conditions for multiplexing

## Whether to support multiplexing between different resources not confined within a sub-slot

* Option 1: Support if the latency requirement is met
  + HW, vivo, Samsung, Spreadtrum, Xiaomi, CMCC, Sharp, Samsung, DCM
  + Arguments:
    - For the case of the HP HARQ-ACK overlapping with the LP HARQ-ACK, the LP HARQ-ACK is often scheduled earlier than the HP HARQ-ACK, and would occupy more than one sub-slot (or slot-based). If the multiplexing case is not allowed, the spectrum efficiency of eMBB services would be greatly degraded due to the frequently dropping of LP HARQ-ACK.
* Option 2: Multiplexing of low priority HARQ-ACK and high priority HARQ-ACK/SR only if the PUCCH resource for the low priority HARQ-ACK is confined within the sub-slot configured for the high priority HARQ-ACK.
  + CATT, Nokia, LG
* Option 3: Multiplexing is allowed only if the resulted PUCCH is confined within the sub-slot of the HP-PUCCH sub-slot.
  + MTK, NEC
  + Arguments:
    - Multiplexing between PUCCHs spanning different sub-slot/slot durations, raises a lot of concern and some HP-PUCCHs could be dropped or delayed in multiple scenarios.
    - Multiplexing between PUCCHs on different sub-slot/slot lengths is not supported, then this functionality will be rarely used in practice and if the gNB wants to use it then it needs to configure sub-slot with the same duration for eMBB which will limit the PUCCH durations used for eMBB.
* Option 4: Multiplexing of low-priority PUCCH and high-priority PUCCH, when feasible, is allowed only if this multiplexing is done on a high-priority PUCCH resource. In addition:
  + UE does not expect an overlap between the resulting PUCCH resource to be used for multiplexing and another high-priority PUCCH;
  + and if the resulting PUCCH resource overlaps with a low-priority PUCCH, the low-priority PUCCH is then dropped.
  + Nokia

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| Company | Comments |
| LG | We prefer Option 2 (as added in the above). We are wondering how latency requirement could be met between LP HARQ-ACK PUCCH and multiple sub-slot HP HARQ-ACK PUCCHs overlapped with the LP HARQ-ACK PUCCH. |
| Sony | Option 1 |
| CMCC | Option 1 |
| Sharp | Option 1.  A HP PUCCH resource can be selected within the same subslot of the original HP PUCCH for multiplexing of HP and LP UCI, the latency is not an issue. Thus, the multiplexing should be supported if the LP PUCCH can be fully dropped by the HP PUCCH with current dropping timeline. |
| Samsung | Support Option1  If gNB would like to only support multiplexing between different PUCCH resources not confined within a sub-slot, gNB can simply configure a same sub slot length for the 2 PUCCH-Config. If this case is not supported, the scheduling flexibility and LP traffic performance will be degraded.  Option 2 is not realistic (e.g. PUCCH resource for eMBB is not confined in 2/7 symbols).  Option 3 is functionally equivalent  Option 3 and Option 4 are detailed solutions under Option 1. Option 3 is practically equivalent to Option 4. We prefer Option 4 as it is simpler for a UE. |
| DOCOMO | Option 1 |
| InterDigital | Yes, multiplexing between different resources not confined within a sub-slot should be supported.  Support Option 1 assuming it means latency requirement of the HP PUCCH.  Option 2 seems too restrictive. In a typical case where LP PUCCH is over 1 slot and HP PUCCH is over 1 sub-slot, LP PUCCH would always be dropped.  Option 3 makes sense as it ensures that HP UCI is not delayed  Option 4 main bullet and first sub-bullet also makes sense. However, the second sub-bullet is unclear. What low-priority PUCCH is this talking about? |
| NEC | Option 3. |
| Intel | Support Option 1. Option 3 and 4 (main bullet) are special cases of Option 1 |
| TCL | Option 1 |

#### 1st round proposal and discussion

Potential proposal 2.2.1:

For multiplexing UCIs of different priorities in a PUCCH in R17,

* Support of multiplexing between different resources not confined within a sub-slot if the latency requirement is met.

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## Whether to support multiplexing in case a PUCCH overlaps with more than one PUCCH

* Option 1: Leave this question open before the UCI multiplexing rule for two overlapping PUCCHs is clear.
  + HW, Sharp
  + Arguments:
    - The final multiplexing result depends on the specific multiplexing order.
* Option 2: Support if conditions (e.g. multiplexing timeline, latency requirement, specific overlapping scenarios) are met

vivo, Samsung, Nokia, Lenovo/Moto, Intel (consider joint multiplexing instead of two-step approach), Spreadtrum (joint multiplexing method can be considered instead of the two step approach in Rel-16), Xiaomi (only multiplex the slot based PUCCH and the first subslot PUCCH resource), CMCC, LG, Samsung, DCM, NEC

Nokia proposal:

*Proposal 3.9: For handling the scenarios with more than two overlapping channels of different priorities, down-select between the following two alternatives:*

* *Alt.1: Allow a single checking/multiplexing step between channels of different priorities, where in case multiplexing is feasible:* 
  + *UE does not expect an overlap between the resulting resource to be used for multiplexing and a high-priority PUCCH;*
  + *and if the resulting PUCCH resource overlaps with a low-priority PUCCH, the low-priority PUCCH is then dropped.*
* *Alt.2: The UE doesn’t expect to multiplex channels with different priorities, i.e. UE drops the low-priority channel(s).*

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| Company | Comments |
| LG | Option 2 is preferred (as added in the above). We are understanding this case is differentiated from the above issue 2.2.1, in terms of whether the overlapping PUCCHs are all within a same time unit (all are within a same slot or sub-slot in this case). |
| Sony | Clarify whether this means more than 2 PUCCHs carrying HARQ-ACK or is this 2 PUCCH carrying HARQ-ACK + another one or more PUCCH carrying SR? |
| CMCC | Support multiplexing in case a LP PUCCH overlaps with more than one HP PUCCH with principle of ensuring the performance of each HP PUCCH. |
| Sharp | It is better to discuss this after two channel collision case is concluded. |
| Samsung | Option 2  However, this issue can be revisited later. A solution should be simple as this case is not as important as the previous one (e.g. not as likely to have multiple non-overlapping LP PUCCHs in a same slot). |
| InterDigital | Option 2 |
| NEC | Support option 2 |
| Intel | Option 2 According to the agreement, following is already supported which is one example of the issue.   * Multiplexing a low-priority HARQ-ACK, a high-priority HARQ-ACK and a high-priority SR into a PUCCH. |
| TCL | Option 2 |

#### 1st round proposal and discussion

Potential proposal 2.2.2:

For multiplexing UCIs of different priorities in a PUCCH in R17,

* Support multiplexing in case a PUCCH overlaps with more than one PUCCH if conditions (e.g. multiplexing timeline, latency requirement, specific overlapping scenarios) are met.
  + FFS details.

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## Timeline requirements

* Option 1: Reuse R15 timeline (or as the starting point)
  + HW, vivo, CATT, IDC, Spreadtrum, Xiaomi, CMCC, Sharp, NEC
* Option 2: Consider additional conditions
  + LGE, DCM
  + Arguments:
    - A processing time (symbol) margin may require to be added to the current timeline (for intra-priority multiplexing in Rel-16) considering additional inter-priority multiplexing.
    - The timing of the last symbol in the PUCCH resource selected to multiplex the LP UCI and HP UCI, may need to be checked whether it is allowable in terms of latency from the perspective of the HP UCI.

MTK proposal:

*Proposal 3: Guard gap timeline of the new multiplexed PUCCH is of the earliest PUCCH*

DCM proposal:

* *Define new timeline for multiplexing UL channels with different priorities. The timeline can be as follows:*
  + *New , i.e. , is defined; is the first symbol of the latest PUCCH or PUSCH on which other UL channels are multiplexed among a group overlapping PUCCHs and PUSCHs in a slot as shown in Fig.2 below.*
  + *UE checks whether the is not before a symbol with CP starting after symbol after a last symbol of the corresponding PDSCH or corresponding SPS PDSCH release, where should be discussed carefully considering UE complexity on the multiplexing with different priorities.*
  + *If the timeline requirement is met, UE multiplexes the LP PUCCH and HP PUCCH using PUCCH resource for HP UCI.*
  + *Otherwise, UE drops LP PUCCH and transmits only HP PUCCH as long as the Rel-16 prioritization timeline (i.e. ) is met.*

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| Company | Comments |
| Sony | Option 1 as a starting point. We need at least to satisfy Rel-15 timeline. |
| CMCC | Option 1 |
| Sharp | As a baseline, UCI multiplexing is allowed if the LP PUCCH channel can be fully dropped by the existing timeline. Otherwise, if the LP PUCCH transmission already starts, the Rel-16 dropping method should be applied. FFS if extra processing delay is needed upon the dropping timeline for UCI multiplexing. |
| Samsung | TBD |
| DOCOMO | We prefer Option 2 for more possibility of multiplexing, which would lead to better eMBB performance. The following is what is in our mind. Basically, difference from Rel-15 multiplexing timeline is newly defined . is defined as the first symbol of the latest PUCCH or PUSCH on which other UL channels are multiplexed among a group overlapping PUCCHs and PUSCHs in a slot. Then, UE checks the time gap between and the corresponding PDSCH or PDCCH. There can be two cases; Case 1: the PUCCH on which other UL channels are multiplexed is earlier, and Case 2: the PUCCH on which other UL channels are multiplexed is later. For Case 1, there is no difference for UE behavior from Rel-15 multiplexing as the definition of is same as . In other words, there is no UE complexity. For Case 2, is different from but still there may not be UE complexity because the partial cancellation or partial transmission of non-overlapping UL channel is supported in Rel-16. Potential complexity that needs to be considered is the processing time for encoding the multiplexed UCI but in the equation can take it into account. |
| InterDigital | Option 1. However, there is also requirement for the last symbol (see issue 2.3.4) |
| NEC | Support option 1. Rel-15 timeline can be a starting point. |
| Intel | Option 1 can be a starting point |
| TCL | Option 1, the timeline condition in Rel-15 could be a starting point.. |
| QC | Option 1. Reuse Rel-15 timeline seems sufficient enough, because Rel-15 timeline is defined with respect to UL and DL processing capabilities, which is transparent/orthogonal to what priorities of the channels are. Adding two different priorities into the multiplexing scenario does not impact the decision on timeline. |

#### 1st round proposal and discussion

Potential proposal 2.2.3:

For multiplexing UCIs of different priorities in a PUCCH in R17,

* Reuse R15 timeline as the starting point.
* FFS additional conditions.

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## Other conditions

* HARQ-ACK codebook types for multiplexing
  + Case a) Multiplexing of LP Type-1 HARQ-ACK and HP Type-1 HARQ-ACK
  + Case b) Multiplexing of LP Type-2 HARQ-ACK and HP Type-2 HARQ-ACK
  + Case c) Multiplexing of HP Type-1 HARQ-ACK and LP Type-2 HARQ-ACK
  + Case d) Multiplexing of HP Type-2 HARQ-ACK and LP Type-1 HARQ-ACK

Samsung proposal:

*Proposal 4: Support LP Type-1/Type-2 HARQ-ACK codebook multiplexing with HP Type-1/Type-2 HARQ-ACK codebook on a same PUCCH. Consider solutions to ensure the reliability of multiplexing of two HARQ-ACK codebooks with different priorities. FFS whether to support multiplexing of HARQ-ACK codebooks of different types.*

* + HW, vivo, CATT

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| Company | Comments |
| Samsung | Prioritize cases a) and b)  The scenarios of Cases c) and d) need clarification. |
| Intel | Prioritize cases a) and b) |
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## Details for multiplexing schemes

## How to encode the UCIs with different priorities (e.g. separate coding vs. joint coding)

* Option 1: Separate coding
  + HW, CATT, Samsung, Nokia, Spreadtrum, DCM, CMCC, ETRI, Sharp, WILUS, LG (baseline)
  + Arguments:
    - Joint coding cannot provide distinguished latency/reliability protections for UCIs of different priorities.
    - For Type-2 HARQ-ACK codebook, the size is determined by the DAI values and a miss detection of a ‘last’ DCI format can lead to UE and gNB have different understanding of the size of HARQ-ACK codebook (e.g. in case of single-cell operation). In such case, separate coding can also help HP UCI detection to not be affected by an incorrect assumption for the size of the LP HARQ-ACK codebook.
  + Problems:
    - New mapping rules and resource determination scheme need to be defined.
* Option 2: Joint coding
  + CATT, Sharp, LG (for some cases) , Intel
  + Arguments:
    - Simple and the current multiplexing scheme can be reused as much as possible.
  + Problems:
    - Since only one coding rate is used for joint coding, the UE must either sacrifice the reliability of the HP UCI if a high coding rate is selected, or provide an over-designed reliability for the LP UCI leading to a great resource waste if a low coding rate is selected.

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| Company | Comments |
| LG | We also prefer separate coding as baseline. On the other hand, for some cases where UCI payload size of a priority is relatively small, it would be better to apply joint coding (rather than separate coding) for the cases. |
| Sony | Option 1. Make sense to have separate coding since LP & HP UCI have different reliability requirements. |
| Sharp | Both separate coding and joint coding should be supported.  Separate coding can satisfy different reliability requirements and is more resource efficient with large payload. Joint coding is simpler and should be applicable for small payload size. For example, for up to 2 bits of HARQ-ACK for each codebook, joint coding can allow joint reporting use PUCCH format 0/1.  In general, joint coding is preferred for small payload, separate coding is better for large payload. The conditions for code method determination should be further discussed. |
| Samsung | Option 1 as baseline. Can consider possibility for option 2 for some cases with small payloads where coding gain from separate coding. |
| InterDigital | Option 1 as a baseline. Joint coding could be considered for smaller payload size unless it creates codebook ambiguity issue. |
| NEC | Both separate coding and joint coding should be supported. It is related to the multiplexing schemes and UCI payload size of each priority, for example, if LP HARQ-ACK is bundled as 1 bit when multiplexed with HP HARQ-ACK, it seems joint coding is sufficient. |
| Intel | Option 2 should be baseline since it can build upon legacy design and may require less specification efforts. Schemes such as threshold on LP UCI payload, bundling can be considered so that reliability of HP UCI is minimally impacted. |
| QC | In general, we have concerns on separate encoding.   1. Need new rate matching and RE mapping rule for HP UCI and LP UCI mux on PUCCH, and HP UCI and LP UCI multiplexing on PUSCH. Quite significant spec impact is a factor we need consider. On the other hand, if joint encoding is adopted, then Rel-15 RM and RE mapping rules can be reused. 2. How many Polar encoder UE needs to budget for the worst case? It seems 6 to me: HP HARQ-ACK, LP HARQ-ACK, HP CSI-part 1, LP CSI-part 1, HP CSI-part 2, LP CSI-Part 2, if RAN1 allow simultaneous HP and LP CSI. Even if considering to drop LP CSI, it seems 4 Polar encoder is needed for the worst case, which increase UE implementation complexity. Of course, if it is well justified, we are OK to accept proposal which increase UE complexity and cost. However, we don’t see strong justification to do separate encoding.   The advantage of separate encoding is not well justified. Please see the following.  Regarding this “Joint coding cannot provide distinguished latency/reliability protections for UCIs of different priorities.” – If UE compress LP UCI and treat compressed HARQ-ACK as if it is HP UCI. Latency/reliability of both HP/LP UCI can be achieved. For the lost info due to compression, if gNB want, gNB can schedule reTx of the LP UCI by type-3 codebook for HARQ-ACK for example. Because they are LP, certain delay is tolerable. One should also notice that, there are advanced compression techniques (rather than simple bundling of UCI) which can minimize the information loss due to compression.  Regarding this “For Type-2 HARQ-ACK codebook, the size is determined by the DAI values and a miss detection of a ‘last’ DCI format can lead to UE and gNB have different understanding of the size of HARQ-ACK codebook (e.g. in case of single-cell operation). In such case, separate coding can also help HP UCI detection to not be affected by an incorrect assumption for the size of the LP HARQ-ACK codebook.” – Unless using separate PUCCH resources to transmit HP and LP UCI, I don’t see separate encoding helps to resolve the missing last DCI issue. If LP and HP UCI are put together in a PUCCH resource, that resource set is determined based on the total UCI size. Missing last DCI can change the resource set and separate encoding does not offer any help here. Furthermore, unless gNB always guarantee PRI in last DCI is the same as PRI in previous DCI, otherwise missing the last DCI will lead to a wrong PRI and UE ends up using a wrong PUCCH resource to transmit HP+LP UCI. Separate encoding does not help neither in this error event. |

**Other proposals:**

vivo proposal:

*Proposal 3: For encoding the UCIs with different priorities, it should be clarified firstly whether the number of separately encoded UCIs need be extended for both PUCCH and PUSCH.*

#### 1st round proposal and discussion

Potential proposal 2.3.1:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17

* Support separate coding for HP HARQ-ACK and a LP HARQ-ACK.
* FFS whether joint coding is also supported for some cases.

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## How to guarantee the target code rate (e.g. payload control, multiplexing priority, LP HARQ-ACK compression/compaction)

* Option 1: Separate coding. If no enough resource is left for LP UCI,
  + Configure two coding rates for HP UCI and LP UCI.
  + Reuse the coding rates of HP and LP UCI on their original PUCCH resource.
  + HP UCI is mapped first. If no enough resource is left,
    - Option 1a: LP UCI is dropped.
      * HW, vivo
    - Option 1b: LP HARQ-ACK is partially dropped.
      * CATT, LGE, , DCM
      * Problem: the priority order within the low-priority HARQ-ACKs should be clarified, e.g., based on scheduling order or resource order.
    - Option 1c: LP HARQ-ACK is compressed/bundled.
      * CATT, LGE (bundling for LP HARQ-ACK in spatial domain and/or CBG domain), Nokia (bundled), MTK, OPPO, ~~CMCC?,~~ NEC, WILUS, Sharp, DCM
* Option 2: Joint coding. The maximum number of LP UCI is configured to X bits.
  + vivo

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| Company | Comments |
| Sony | Option 1. It is sufficient to say at this point that some of the LP UCI information will be lost, e.g. via dropping or bundling. The details can be FFS. |
| CMCC | Option 1 with the code rate determination FFS. |
| Sharp | For separate coding, two maximum code rates may be configured for HP PUCCH, or a scale factor can be configured to determine the LP UCI code rate. If the resource is not enough, LP UCI compression and dropping can be considered. |
| Samsung | Option 1a as starting point. Option 1c with spatial domain bundling can also be considered as the first step (separate configuration whether to apply than in Rel-15). |
| DOCOMO | Option 1b or 1c |
| InterDigital | Option 1c. |
| NEC | We support HARQ-ACK compression/bundling but do not support to always bundle LP HARQ-ACK. Since URLLC is designed for high reliability, URLLC HARQ-ACK codebook may be carrying ACK in most cases. In such cases, we think that multiplexing original eMBB feedback with compressed URLLC feedback can be a better solution. Therefore, decision that which codebook is compressed can be based on the codebook content as follows.  - If URLLC codebook carries ACK only or NACK only: if eMBB codebook carries both ACK and NACK, bundle URLLC HARQ-ACK codebook bits into 1 bit and append at the end of the eMBB codebook. Otherwise, bundle eMBB codebook bits into 1 bit and append at the end of the URLLC codebook.  - If URLLC codebook carries both ACK and NACK, bundle eMBB HARQ-ACK codebook bits into 1 bit and append at the end of the URLLC codebook. In this case, if bundled eMBB feedback indicates NACK, full eMBB codebook is transmitted later. Features, e.g. Type 3 codebook, enhanced Type 2 codebook and NNK1, developed in Rel-16 can be used for transmission of original eMBB HARQ-ACK feedback later.  Therefore, we propose joint coding such that one of the two codebooks is bundled to one bit. |
| Intel | Option 2, which should be revised as follows. We actually did not propose separate coding, so Intel is removed from Option 1b   * Option 2: Joint coding.   + Option 2a: The maximum number of LP UCI is configured to X bits.     - Vivo   + Option 2b: A threshold on LP HARQ-ACK payload can be configured and LP HARQ-ACK can be partially dropped, if above threshold.     - Intel   We added our proposal below. |
| QC | We prefer Option 2. The maximum number of LP UCI is configured to X bits. Compression/bundling is performed if the # LP UCI bits exceeds X.  However, we suggest to hold on discussion on this until the separate encoding vs joint encoding discussion is settled. |

IDC proposal:

*Proposal 4: For multiplexing PUCCH transmissions of different priorities:*

* *Multiplexing is over a high-priority PUCCH resource;*
* *Multiplexing can only occur if a maximum code rate applicable to high-priority UCI is not exceeded*

CMCC proposal:

*Proposal 7: For determining the code rates for HP UCI and LP UCI when multiplexing, the following alternatives can be further studied:*

* + *Two maxCodeRates are configured for PUCCH resource used for multiplexing, one is used for LP UCI and the other is used for HP UCI.*
  + *One maxCodeRate is configured for PUCCH resource used for multiplexing, the configured maxCodeRate is used for UCI with the corresponding priority indicated by the last DCI format, the code rate of UCI with the other priority is adjusted based on the configured maxCodeRate of the PUCCH resource for multiplexing, or determined by the configured maxCodeRate of the original PUCCH resource if exists.*

NEC proposal:

*Proposal 1: Multiplexed feedback consists of original codebook for one service followed by one bit representing the result of bundling the other codebook’s bits. Content of the two codebooks determine which codebook’s bits are bundled.*

*Proposal 3: Support transmitting 1-bit indicator with multiplexed HARQ-ACK feedback as proposed in proposal 1 to explicitly indicate which codebook is bundled.*

ETRI proposal:

*Proposal 3: Further study how to adjust the power of PUCCH for payload from the other priority.*

*Proposal 4: Whenever being transmitted, all the LP HARQ-ACK bits are multiplexed.*

Intel proposal:

*Proposal 4: Support the following for multiplexing HP and LP HARQ-ACKs onto a PUCCH:*

* *Multiplexed HARQ-ACK payloads are transmitted using PUCCH configuration of HP codebook*
* *LP and HP HARQ-ACK payload bits are concatenated and jointly encoded*
* *LP HARQ-ACK payload bits can be partitioned or a threshold on the payload can be considered to maintain target code rate.*

#### 1st round proposal and discussion

Potential proposal 2.3.2:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,

* For separate coding for HP HARQ-ACK and a LP HARQ-ACK,
  + Two coding rates can be separately configured for HP HARQ-ACK and a LP HARQ-ACK.
  + Reuse the coding rates of HP HARQ-ACK and a LP HARQ-ACK on their original PUCCH resource.
  + HP HARQ-ACK is mapped into the PUCCH resource first. Then LP HARQ-ACK is mapped into the PUCCH resource left.
    - FFS solutions if no enough resource is left for LP HARQ-ACK.
  + FFS other details

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## How to determine the PUCCH resource used for multiplexing (e.g. HP or LP PUCCH resource, or a dedicated PUCCH resource for the multiplexing)

**For multiplexing between HARQ-ACKs with different priorities:**

* Option 1: Determine the PUCCH resource sets for HP and LP UCIs respectively according to the total payload size by merging LP UCI and HP UCI. Select one resource between the two indicated by DCI using some rule.
  + Option 1a: Select the HP HARQ-ACK resource
    - CATT, ZTE, Nokia, IDC, Intel, Pana, MTK, Spreadtrum, OPPO, Sony, NEC, Sharp
  + Other sub-options:
    - LGE (e.g. using configured priority or resource size or symbol timing)
    - DCM (If there is no resource set to accommodate total UCI bits, new cyclic shift scheme or eMBB PUCCH resource can be used instead.)
    - Xiaomi (PUCCH resource from the PUCCH resource sets with lower maximum coding rate)
    - CMCC (depending on the priority indicator in the last DCI format, if dedicated PUCCH resource for multiplexing is not configured)
    - WILUS (select a PUCCH resource without considering sub-slot boundary and select a PUCCH resource in a symbol set where the first symbol of the set is the earliest symbol among overlapping PUCCHs and the last symbol of the set is the latest symbol among overlapping PUCCHs.)
* Option 2: Use a dedicated PUCCH resource, e.g. configuring additional PUCCH resource set (on top of the PUCCH resource sets configured per each of LP and HP) which is dedicated for the multiplexing/transmission of UCIs with different priority
  + LGE, HW, CMCC, ETRI
  + Arguments:
    - DCI mis-detection issue

**Other proposals:**

IDC proposal:

*Proposal 3: A necessary condition for the UE to multiplex PUCCH and/or PUSCH transmissions of different priorities is that the last symbol of the resource onto which multiplexing takes place is not later than the last symbol of the resource of a high-priority transmission.*

Nokia proposal:

*Proposal 3.2: RAN1 to study how to avoid discrepancy between the UE and the gNB on the determination of PUCCH resource set and number of RBs for UCI containing multiplexed high-priority and low-priority HARQ-ACKs.*

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| Company | Comments |
| Sony | Option 1a. The HP PUCCH is scheduled to handle the URLLC reliability & latency requirement, therefore this is the logical resource to use to ensure the reliability of the HP UCI is met. |
| CMCC | The “last DCI format” can be either the DCI scheduling HP HARQ-ACK or the DCI scheduling LP HARQ-ACK, especially for DL heavy TDD frame structure with only one UL slot in a periodicity. Hence either HP PUCCH resource or LP PUCCH resource may be used, depending on the priority indicator in the last DCI format.  In addition, we think the PUCCH resource determination and guarantee the target code rate of HP HARQ-ACK can be separately discussed, i.e. separate encoding and mapping of UCI with different priorities with different coding rates can be used to guarantee the reliability of HP UCI.  Alternatively, dedicated PUCCH resource which is configured for multiplexing UCIs with different priorities can also be considered. |
| Sharp | Option 1a. The HP PUCCH resource is configured to satisfy the URLLC requirements. The multiplexing of LP UCI should not sacrifice the HP UCI performance. |
| Samsung | Option 1.  DCI mis-detection issue can be avoided by other mechanisms. E.g., explicit indication of multiplexing/UL DAI of LP HARQ-ACK.  A dedicated PUCCH resource is not necessary. Moreover, the dedicated PUCCH resource may bring up other issues. E.g., overlapping with another PUCCH. |
| InterDigital | Option 1a, to ensure reliability of HP UCI. |
| NEC | Option 1a. We share same view with Sony. |
| Intel | Option 1a, HARQ-ACK resource according to HP codebook configuration |
| QC | We prefer Option 1a in general, except for a few corner cases that resource selection is performed. For example, case 1: HP HARQ-ACK in PF1 overlaps with LP SR in PF1; case 2: LP HARQ-ACK in PF1 overlaps with HP SR in PF0; Case 3: HP SR in PF1 overlaps with LP HARQ-ACK in PF0; Case 4: HP SR in PF1 overlap with LP HARQ-ACK in PF1.  Regarding option 2, we don’t see the benefit of it, despite its cost of additional resource reservation dedicated for multiplexing. Missing last DCI is still an issue with option 2. Given that the UCI range of multiplexed HP and LP UCI could be large, we assume multiple dedicated resources for multiplexing are needed. Then a PRI is needed to indicate which dedicated resource to use. With that, missing last DCI still cause confusion because UE may use a wrong PRI to transmit PUCCH in a wrong PUCCH resource. |

#### 1st round proposal and discussion

Potential proposal 2.3.3:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,

* If no dedicated PUCCH resource is configured,
  + Determine the PUCCH resource sets for HP HARQ-ACK and LP HARQ-ACK respectively according to the total payload size by merging LP HARQ-ACK and HP HARQ-ACK.
  + Select the HP HARQ-ACK resource between the two indicated by DCI
* FFS whether dedicated PUCCH resources can be configured for the multiplexing HP HARQ-ACK and LP HARQ-ACK.

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## How to minimize impact on the latency for high-priority HARQ-ACK?

* Option 1: Multiplexing LP UCI with HP UCI is allowed only when the PUCCH carrying the multiplexed UCI ends no later than the PUCCH carrying HP UCI.
  + HW, ITRI
* Option 1a: The latency requirement can be defined as the ending symbol of PUCCH resource for multiplexed UCI transmission is not later than X symbols after the ending symbol of PUCCH for the higher priority UCI. FFS value of X.
  + CATT, LG, CMCC

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| Company | Comments |
| LG | We prefer Option 1a (as added in the above). We think Option 1 which always requires early ending of multiplexed PUCCH than HP PUCCH, would force unnecessary tight requirement in some cases. |
| Sony | If the HP PUCCH resource is used to carry the mux UCI then the latency is always met. Option 1 will be automatically met. |
| Sharp | Not sure if this is an issue. All HP PUCCH resources should be configured to satisfy the latency requirements.  Therefore, if a HP PUCCH resource is used, the new selected HP PUCCH should be within the same subslot/slot of the original HP PUCCH resource.  So, this problem can be discussed after PUCCH resource determination in 2.3.3. |
| Samsung | Both options should not be supported.  The latency can be ensured by gNB scheduling. E.g., sub-slot length for PUCCH configuration. If HP PUCCH resource is used as the result PUCCH after MUX, the latency can be controlled within the HP sub-slot boundary.  Note that UCI can be multiplexed in the PUSCH in Rel-16 and there are no conditions – it is a gNB implementation issue. |
| DOCOMO | Slightly prefer Option 1a but this could be discussed with the timeline in 2.2.3. |
| InterDigital | Option 1. However, this may not add restriction in practice if multiplexing is on a HP PUCCH. |
| NEC | Option 1 implies that the latency requirement for HP UCI is always met. |
| Intel | Ok with either option |
| TCL | Option 1 could guarantee the low latency of HP UCI. |
| QC | We think option 1 and 1a are very similar. A WF can be formulated based on the commonality of the two schemes. For example, in option 1a, if X=0, then it seems automatically reduced to option 1. In other words, option 1 seems a special case of option 1a. |

#### 1st round proposal and discussion

Potential proposal 2.3.4:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,

* The latency requirement is defined as the ending symbol of PUCCH resource for multiplexed UCI transmission is not later than X symbols after the ending symbol of PUCCH for the higher priority UCI.
  + FFS value of X.

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## Explicit indication for enabling multiplexing

* Option 1: Support explicit indication
  + vivo (semi-static and dynamic indication), E/// (dynamic), Samsung, ZTE, Nokia (dynamic), QC (RRC, robust and simpler), Sony (dynamic), Intel (configured DCI indication), ETRI (RRC+DCI field)
  + Arguments:
    - Straightforward method to select from Rel-16 and Rel-17 behaviors
    - Semi-static indication for periodic or predictable URLLC transmissions. Dynamic indication based on multiplexing conditions, e.g. latency requirement, channel condition, number of UCI bits.
* Option 2: Not support
  + MTK
  + Arguments:
    - Very complex to handle at the UE side and requires a lot of implementation effort as the UE needs to accommodate two scenarios for each case which will complicate the implementation.

**Further enhancements:**

Samsung proposal:

*Proposal 2: The UCI types with first priority that can be multiplexed on a PUCCH/PUSCH of a second priority are configurable by the network.*

QC proposal:

*Proposal 12: If the Rel-17 intra-UE multiplexing feature is enabled via RRC configuration, UCI multiplexing is performed conditioning on the delay of starting time and/or ending time of high priority UL transmissions due to multiplexing is less than a preconfigured delay threshold.*

WILUS proposal:

*Proposal 6: TDMed or FDMed mapping can be used to map UCIs with two priorities in a PUCCH.*

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| Company | Comments |
| Samsung | Option 1. UE can handle multiplexing (and can handle no multiplexing). There is no complexity issue by indicating one and allows the network to handle a variety of services and conditions. |
| Intel | Option 1 |
| TCL | Option 1 |
| QC | First of all, I think the issue is about semi-static RRC configuration vs dynamic indication by DCI. The issue is not about whether support explicit indication or not, if I understand the situation clearly.  Regarding semi-static RRC configuration vs dynamic indication by DCI, RRC configuration to enable/multiplexing has to be supported as a baseline. This is not just for CG and DL SPS, but also for DG PDSCH and DG PUSCH. The reason is because: for fallback DCI, or for UE just go through initial access where the size of non-fall back DCI is not configured yet, the dynamic indication (either option 1a or option 1b) can not work.  The situation is similar to the discussion of semi-static beta configuration vs dynamic beta indication in Rel-15. Semi-static beta configuration has be introduced as a baseline because the system has to work when dynamic beta indication is not available.  So, we should agree on semi-static enabling of multiplexing between HP/LP first. Then we discuss if dynamic enabling of this feature is needed. |
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#### 1st round proposal and discussion

Potential proposal 2.3.5:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,

* Support a mechanism for gNB to enable/disable the multiplexing.
  + Down-select from the following options for the mechanism:
    - Option 1: RRC configuration
    - Option 2: DCI indication
    - Option 3: RRC configuration + DCI indication
  + FFS other details.

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## Multiplexing HARQ-ACK and SR with different priorities

E/// proposal:

[*Proposal 5 When PUCCH with HP SR overlaps with PUCCH with LP HARQ-ACK:*](#_Toc54415344)

[*i. For 1-2 LP HARQ-ACK bits: The PUCCH resource for HARQ-ACK is used for multiplexing of the HP SR and LP HARQ-ACK. If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.*](#_Toc54415345)

[*ii. For more than 2 LP HARQ-ACK bits: Rel-15 rules are used for multiplexing HARQ-ACK and SR in a PUCCH resource. If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the PUCCH resource.*](#_Toc54415346)

[*Proposal 6 When PUCCH with HP HARQ-ACK/SR overlaps with PUCCH with LP HARQ-ACK:*](#_Toc54415347)

[*i. First, a PUCCH resource set associated to HP HARQ-ACK based on the total number of HP HARQ-ACK/SR and LP HARQ-ACK is determined. Then, a PUCCH resource in the PUCCH resource set to carry both HP and LP HARQ-ACK based on the last DCI corresponding to the HP HARQ-ACK is determined.*](#_Toc54415348)

LGE proposal:

*Proposal #7: Consider to support HARQ-ACK + SR on HARQ-ACK PUCCH for the combination between LP HARQ-ACK of up to 2 bits on PF0 and HP SR on PF0/1.*

*Proposal #8: Consider to support HARQ-ACK + SR on HARQ-ACK PUCCH for the combination between LP HARQ-ACK of up to 2 bits on PF1 and HP SR on PF0.*

ZTE proposal:

*Proposal 3: Adopt the following rules to multiplex high priority SR and low priority HARQ-ACK.*

|  |  |  |  |
| --- | --- | --- | --- |
| *HARQ-ACK*  *SR* | *PUCCH format 0* | *PUCCH format 1* | *PUCCH format 2/3/4* |
| *PUCCH format 0* | *For positive SR, the UE transmits the PUCCH in the resource using PUCCH format 0 in PRB(s) for SR. The same way in Rel-15 can be reused for the UE to determine the value of  and  for computing the value of cyclic shift .*  *For negative SR, the UE transmits only a PUCCH with HARQ-ACK information.* | | *For positive SR, the UE transmits only a PUCCH with the SR and drops the PUCCH with HARQ-ACK information.*  *For negative SR, the UE transmits only a PUCCH with HARQ-ACK information and drops the PUCCH with negative SR.* |
| *PUCCH format 1* | *For positive SR, the UE transmits the PUCCH in the resource using PUCCH format 1 in PRB(s) for SR. The value of cyclic shift of sequence, i.e., , of this PUCCH format 1 is determined by HARQ-ACK, and the bit, i.e., b(0), of this PUCCH format 1 is determined by SR*  *For negative SR, the UE transmits only a PUCCH with HARQ-ACK information and drops the PUCCH with negative SR.* | *Reuse Rel-15 rules.* |

Nokia proposal:

*Proposal 3.7: For the scenario where a PUCCH carrying high-priority SR overlaps with a PUCCH carrying low-priority HARQ-ACK, the SR is prioritized and the HARQ-ACK is dropped for all the cases of PUCCH format combinations except the case where both SR and HARQ-ACK are with PUCCH format 1.*

* *FFS whether to allow multiplexing of high-priority SR with PUCCH format 1 and low-priority HARQ-ACK with PUCCH format 1.*

*Proposal 5:*

* *For multiplexing a low-priority HARQ-ACK and a high-priority SR into a PUCCH, following HARQ-ACK/SR PUCCH format combination should be studied.*
  + *High-priority SR and low-priority HARQ-ACK in a resource using PUCCH format 0*
  + *High-priority SR in a resource using PUCCH format 0 and low-priority HARQ-ACK information bits in a resource using PUCCH format 1*
  + *High-priority SR in a first resource using PUCCH format 1 and low-priority HARQ-ACK in a second resource using PUCCH format 1*
  + *High-priority SR and low-priority HARQ-ACK in a resource using PUCCH format 2, 3, or 4*

*Proposal 6:*

* *For multiplexing a low-priority HARQ-ACK, a high-priority HARQ-ACK and high-priority SR into a PUCCH, following two procedures are studied.*
  + *Option 1: UE first resolve the overlapping for PUCCH transmission of high-priority HARQ-ACK and high-priority SR. After resolving the overlapping, multiplexing of low-priority HARQ-ACK is handled.*
  + *Option 2: How UCIs are concatenated up to certain size is handled as one step procedure, e.g., with the priority of high-priority HARQ-ACK > high-priority SR > low-priority HARQ-ACK.*

DCM proposal:

*Proposal 4:*

* *Agree the table for UE behavior on multiplexing eMBB HARQ-ACK and URLLC SR as a baseline. Further considerations are needed for down-selection.*

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|  | **URLLC SR PF0** | **URLLC SR PF1** |
| **eMBB HARQ-ACK PF0** | * Same as Rel-15/16 multiplexing for same priority using URLLC PF0 | * Opt 1:   + If latency requirement can be fulfilled for eMBB PF0 resource, same as R15/R16 multiplexing for same priority, i.e. URLLC SR and eMBB HARQ-ACK multiplexed on eMBB PF0 resource.(possible reliability issue for URLLC SR);   + Otherwise, eMBB HARQ-ACK is dropped. * Opt 2: eMBB HARQ-ACK transmitted on URLLC PF1 resource if URLLC SR positive, while eMBB HARQ-ACK transmitted on eMBB PF0 resource if URLLC SR negative. |
| **eMBB HARQ-ACK PF1** | * Opt 1:   + If latency requirement can be fulfilled for eMBB, URLLC SR and eMBB HARQ-ACK multiplexed by the new cyclic shift method on URLLC PF0 resource.   + Otherwise, eMBB HARQ-ACK is dropped. * Opt.2: eMBB HARQ-ACK transmitted on URLLC PF0 resource if URLLC SR positive, while eMBB HARQ-ACK transmitted on eMBB PF1 resource if URLLC SR negative. | * Same as Rel-15/16 multiplexing for same priority |
| **eMBB HARQ-ACK PF2/3/4** | * Same as Rel-15/16 multiplexing for same priority   + Opt.1: using PUCCH resource set assigned for URLLC that can accommodate the total UCI bits.   + Opt.2: using the eMBB PUCCH resource with some restriction, e.g. timeline for latency requirement | |

QC proposal:

***Proposal 2*: In NR Rel-17, if a HARQ-ACK transmission on PUCCH format 0 or PUCCH format 1 collide with one SR, the UE performs the actions in Table 1 to resolve the collision.**

Table 1. Collision resolution for overlapping HARQ-ACK and SR in NR Rel-17

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Ack: PF0, LP | Ack: PF1, LP | Ack: PF0, HP | Ack: PF1, HP |
| SR: PF 0, LP | Same as Rel-15 (i.e., multiplex on HARQ-ACK resource). | Same as Rel-15 (i.e., drop SR) | Multiplex the HARQ-ACK and SR on the HARQ-ACK resource (as in Rel-15), with a power boost to the multiplexed transmission. | Same as Rel-15 (drop SR). |
| SR: PF1, LP | Same as rel-15 (i.e., multiplex on HARQ-ACK resource) | Same as Rel-15 (RB selection) | Multiplex the HARQ-ACK and SR on the HARQ-ACK resource (as in Rel-15), with a power boost to the multiplexed transmission. | RB selection (as in Rel-15) but with the enhancement that, if SR is positive, the power of the PUCCH transmission follows the power of the HARQ-ACK resource. |
| SR: PF0, HP | Use the SR resource to transmit multiplexed SR and HARQ-ACK, with a power boost to the multiplexed transmission. | Perform RB selection (i.e., if SR is negative, then transmit HARQ-ACK on the HARQ-ACK resource. Otherwise, transmit HARQ-ACK on the SR resource.) | Same as Rel-15 | Same as Rel-15 |
| SR: PF1, HP | Perform RB selection (i.e., if SR is negative, then transmit HARQ-ACK on the HARQ-ACK resource. If SR is positive, transmit HARQ-ACK on the SR resource.) | Same as Rel-15 (i.e., RB selection). | Same as Rel-15 | Same as Rel-15 |

*Proposal 3: In NR Rel-17, if a HARQ-ACK transmission on PUCCH format 2/3/4 collide with K SR transmissions including HP SRs and LP SRs, the UE append bits to the HARQ-ACK payload. Furthermore, if any of the HP SR is positive, thebits shall indicate a positive HP SR.*

Xiaomi proposal:

*Proposal 5: Solutions such as direct puncture or treating HP SR as HARQ-ACK/CSI bit in multiplexing can be considered for HP SR on LP PUSCH.*

CMCC proposal:

*Proposal 8: Multiplexing of LP HARQ-ACK and HP SR for all PF combinations are supported in case that the multiplexing conditions discussed above can be met and same multiplexing rule as Rel-15 can be considered.*

*Proposal 9: For multiplexing of HP SR with PF0 and LP HARQ-ACK with PF1, similar multiplexing rule with scenario of SR with PF1 and HARQ-ACK with PF1 can be used.*

Intel proposal:

*Proposal 8: Adopt the following tables for collision handling behavior of SR and HARQ-ACK of different priorities.*

Collision handling HP SR and LP HARQ-ACKs

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| --- | --- | --- | --- | --- |
|  | **HARQ-ACK with PF0** | **HARQ-ACK with**  **PF1** | **HARQ-ACK with PF2** | **HARQ-ACK with**  **PF3 or PF4** |
| SR with PF0 | Multiplexed UCI is transmitted using PF0 on HARQ-ACK resource | Drop HARQ-ACK and transmit SR on SR resource | Multiplexed UCI is transmitted using PF 2 on HARQ-ACK resource or any other valid PUCCH resource based on PF 2 | Drop HARQ-ACK and transmit SR on the SR resource. |
| SR with PF1 | Multiplexed UCI is transmitted using PF 0 or 1 | Multiplexed UCI is transmitted using PF 1 on SR or HARQ-ACK resource |

Collision handling LP SR and HP HARQ-ACKs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **HARQ-ACK with PF0** | **HARQ-ACK with**  **PF1** | **HARQ-ACK with PF2** | **HARQ-ACK with**  **PF3 or PF4** |
| SR with PF0 | Multiplexed UCI is transmitted using PF0 on HARQ-ACK resource | Drop SR and transmit HARQ-ACK on HARQ-ACK resource | Multiplexed UCI is transmitted using PF 2 on HARQ-ACK resource if SR is with PF 0. SR is dropped if it is PF 1 | Multiplex HARQ-ACK and SR according to Rel-15 procedure. |
| SR with PF1 | SR is dropped | Multiplexed UCI is transmitted using PF 1 on HARQ-ACK resource |

## Multiplexing rule and order

E/// proposal:

1. *Resolve overlapping between PUCCH resources based on Rel-15 procedures where the overlapping is resolved starting from the first set of mutually overlapping PUCCH resources in a slot (a.k.a. set Q) until there are no overlapping PUCCH resources in the slot.*
2. *To determine a single PUCCH resource for a set of mutually overlapping PUCCH resources with different priority, drop SR and CSI of low priority, if any. Then, use sub-slot PUCCH resources if there is a sub-slot HARQ-ACK PUCCH in the set, starting from the earlier and smaller sub-slot.*

Samsung proposal:

*Proposal 5: Intra-UE multiplexing should be performed in the following order,*

* *Step1: Multiplexing PUCCH(s) and/or PUSCH(s) with the same priority.*
* *Step2: Multiplexing PUCCH(s) and/or PUSCH(s) with the different priorities.*

vivo proposal:

*Proposal 11: Define UCIs of different priorities multiplexing rule at least for the following cases*

* *LP HARQ-ACK using PF 1 and HP HARQ-ACK and LP SR using PF 0.*
* *HP HARQ-ACK using PF 1 and LP HARQ-ACK and HP SR using PF 0.*

ZTE proposal:

*Proposal 4: For the overlapping between more than two PUCCHs with different priorities UCI, the UE can first resolve overlapping between the same UCI type, and then resolve overlapping between different UCI types.*

Nokia proposal:

*Proposal 3.6: The scenario where a PUCCH carrying high-priority HARQ-ACK+SR overlaps with a PUCCH carrying low-priority UCI is handled in the same way as the scenario where a PUCCH carrying high-priority HARQ-ACK (only) overlaps with a PUCCH carrying low-priority UCI.*

Panasonic proposal:

*Proposal 4: For multiplexing a high-priority HARQ-ACK and a low-priority HARQ-ACK into a PUCCH, after resolving the overlapping for PUCCH transmissions of smaller priority index, UE procedure for multiplexing HARQ-ACK codebooks with different priority indexes should be performed.*

DCM proposal:

*Proposal 5:*

* *For collision handling among LP HARQ-ACK, HP HARQ-ACK, and HP SR, following UE behaviour is proposed:*
  + *Step 1: multiplexing of HP HARQ-ACK and HP SR by following Rel-16 procedure.*
  + *Step 2: multiplexing of the outcome of step 1 and LP HARQ-ACK by following Case 1.*

QC proposal:

*Proposal 4: In NR Rel-17, if a LP HARQ-ACK, a HP HARQ-ACK and an SR collide, the UE shall perform the following two steps*

* *Step 1: multiplex the LP HARQ-ACK and the HP HARQ-ACK by bundling the LP HARQ-ACK into X bits (e.g., X=1) and append the bundled X bits to the HP HARQ-ACK payload, and place the multiplexed HARQ-ACK on the HP HARQ-ACK resource*
* *Step 2: resolve the collision between the multiplexed HARQ-ACK and the SR (if any) by treating the multiplexed HARQ-ACK as high priority transmission, and by using the rules proposed in Table 1 or Proposal 3.*

Xiaomi proposal:

*Proposal 6: The R16 agreement about multiplexing/cancelling order is not applicable in some cases and needs to be reconsidered. It is more nature for UE to operate in a“first come first process” manner.*

CMCC proposal:

*Proposal 4: The low priority PUCCH/PUSCH and the first high priority PUCCH/PUSCH satisfying the multiplexing conditions are multiplexed only if the PUCCH/PUSCH carrying multiplexed UCI(s) and UL-SCH(s) do not overlap with any other high priority PUCCH/PUSCH.*

# Multiplexing UCIs of different priorities in a PUSCH

## Agreements in previous meetings

Agreements:

*Support multiplexing for following scenarios in R17:*

* *Multiplexing a low-priority HARQ-ACK in a high-priority PUSCH (conveying UL-SCH only).*
* *Multiplexing a high-priority HARQ-ACK in a low-priority PUSCH (conveying UL-SCH only)*
* *Multiplexing a low-priority HARQ-ACK, a high-priority PUSCH conveying UL-SCH, a high-priority HARQ-ACK and/or CSI.*
* *Multiplexing a high-priority HARQ-ACK, a low-priority PUSCH conveying UL-SCH, a low-priority HARQ-ACK and/or CSI.*

*For the above multiplexing scenarios,*

* *Support separate configurations of at least beta-offset values (FFS for alpha) for multiplexing with different priority combinations.*
  + *FFS for other separate configurations.*
  + *FFS: value range of beta-offset (e.g. <1).*
* *FFS the conditions, if needed, for multiplexing, e.g.*
  + *FFS: Whether to support multiplexing in case a PUCCH/PUSCH overlaps with more than one PUCCH/PUSCH.*
  + *Timeline requirements.*
* *FFS: details, if needed, of the multiplexing scheme, e.g.*
  + *How to minimize impact on the latency for high-priority HARQ-ACK.*
  + *How to multiplex the HARQ-ACK bits (e.g. multiplexing, bundling)?*
  + *How to encode the UCIs with different priorities (e.g. separate coding vs. joint coding).*
  + *How to guarantee the target code rate (e.g. payload control, multiplexing priority, LP HARQ-ACK compression/compaction).*
  + *Explicit indication for multiplexing.*
  + *Multiplexing rule and order (e.g. HP/LP multiplexing is after resolving collision within the same priority).*
  + *How to handle multiplexing of UCI of different priorities and CG-UCI in a CG-PUSCH*

## Separate configurations for multiplexing with different priority combinations

## Priority combinations for separate beta offset configurations

* Option 1: Separate configurations for different UCI priorities
  + Most of companies
* Option 2: Separate configurations for different UCI/PUSCH combinations
  + QC, Intel

QC proposal:

*Proposal 5: In NR Rel-17, up to four sets of beta offset values can be configured to the UE to indicate separate beta offset values for the following cases:*

* *Multiplexing LP HARQ-ACK/UCI on LP PUSCH*
* *Multiplexing LP HARQ-ACK/UCI on HP PUSCH*
* *Multiplexing HP HARQ-ACK/UCI on LP PUSCH*
* *Multiplexing HP HARQ-ACK/UCI on HP PUSCH*

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| Company | Comments |
| LG | It seems the title of Issue 3.2.1 is to be updated as “Number of separate configurations for beta-offsets”. Besides, observing QC proposal in the above, Option 1 and 2 seem to be the same way. |
| Sony | The title of 3.2.1 is unclear. I take it this is regarding whether to have separate beta-offset configurations depending on the priority of the UCI & priority of the PUSCH. If so, then Sony agrees to have different offsets. |
| Samsung | Option 1 should be supported.  The necessity of Option 2 needs further discussion. |
| InterDigital | Option 2 (if this is about beta offsets, i.e. Proposal 5 above).  For example, the fraction of resources for HP UCI in LP PUSCH needs to be higher than for HP UCI in HP PUSCH since in former case the LP PUSCH may be sent with lower power. |
| CMCC | Option 2  If I understand correctly, separate configurations of beta-offset for different HARQ-ACK codebooks has already supported in Rel-16. In last RAN1 meeting, we have the following agreement and I suppose the “different priority combinations” here means different HARQ-ACK and PUSCH combinations, as listed in QC’s proposal. (Please correct me if I missed something)   * *Support separate configurations of at least beta-offset values (FFS for alpha) for multiplexing with different priority combinations.* |
| NEC | The title of issue 3.2.1 is unclear for us. If our understanding is right that the option 1 means up to two sets beta-offset values can be configured, then we support option 2. |
| Intel | We prefer Option 2 since it includes Option 1 and is more flexible. We added Intel to Option 2.  **Also, note that the following bullet needs to be addressed by the group, but not captured in FL summary.**   * + ***How to handle multiplexing of UCI of different priorities and CG-UCI in a CG-PUSCH***   **In our view, if CG PUSCH is transmitted, then CG-UCI should not be dropped, i.e., it becomes of high priority. We think the topic should be discussed in Intra-UE agenda.** |
| QC | Agree with LG. It is not clear to us the different between option 1 and option 2. I think another way to formulate the issue is: how many sets of beta offset values are needed? Our view is that 4 sets are needs to be configured, as listed in our proposal. I’d like to understand how many sets are needed in option 1 and which UCI/PUSCH scenario is each set for? |

#### 1st round proposal and discussion

Potential proposal 3.2.1:

In NR Rel-17, up to four sets of beta offset values can be configured to the UE to indicate separate beta offset values for the following cases:

* Multiplexing low-priority (LP) HARQ-ACK/UCI on LP PUSCH
* Multiplexing LP HARQ-ACK/UCI on high-priority (HP) PUSCH
* Multiplexing HP HARQ-ACK/UCI on LP PUSCH
* Multiplexing HP HARQ-ACK/UCI on HP PUSCH

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## Value range of beta-offset

* Option 1: Support beta-offset < 1 at least for LP UCI multiplexing on HP PUSCH carrying data
  + HW, E///, ZTE (such as 0.8, 0.5), Nokia (e.g. 0) , Pana (e.g. 0, specific and non-numerical value), MTK, Spreadtrum (e.g. 0), DCM, CMCC, Intel (e.g. 0)
  + Arguments:
    - Better protection of the HP data transmission.

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| Company | Comments |
| Sony | Agree that we should have beta-offset < 1, at least for beta-offset = 0. This should only be applicable when the UCI is LP and the PUSCH is HP (hence the need for separate set of beta-offsets). |
| Samsung | Support Option 1 |
| InterDigital | Agree (Option 1) |
| CMCC | Option 1 |
| NEC | Support option 1. |
| Intel | Support Option 1, however we do not need to capture any condition. It is up to gNB configuration.   * Option 1: Support beta-offset < 1 |
| QC | We don’t see introduce beta<1 is necessary. Beta<1 seems only useful when LP HARQ-ACK is multiplexed on HP PUSCH and it is useless in other scenarios. It seems too much unnecessary effort to introduce this feature only for a single use case. For this particular use case, there are other alternatively to achieve same goal.  Alt 1: use alpha value to protect the HP PUSCH.  Alt 2: compress the LP UCI to reduce the RE usage of UCI thus protect the HP PUSCH.  At least, before the pros and cons of different alternatives are studied/discussed, we don’t think beta<1 should be introduced. |

QC proposal:

*Proposal 6: In Rel-17, if both HP and LP UCI can be piggybacked on a PUSCH at the same time, the beta offset can be indicated via the following:*

* *Option 1: One beta offset field (2 bits) is configured in the DCI that schedules the PUSCH, if the HP and LP UCI are jointly encoded*
* *Option 2: Two separate beta offset fields (in total 4 bits) are configured in the DCI that schedules the PUSCH, if the HP and LP UCI are separately encoded.*

#### 1st round proposal and discussion

Potential proposal 3.2.2:

Support beta-offset < 1 at least for low-priority (LP) UCI multiplexing on high-priority (HP) PUSCH carrying data

* At least beta-offset = 0 is supported. FFS other values.

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## Separate configurations of alpha values?

* Yes
  + HW, LGE, Nokia, Spreadtrum, CMCC, Sony, Samsung, DCM,NEC
  + Arguments:
    - To guarantee HP PUSCH reliability (with LP UCI piggybacking), similar to the reason for beta offset.
    - R16 has supported separate alpha values for HP PUSCH and LP PUSCH.
* No
  + E///, Intel
  + Arguments:
    - The same goal on controlling number of REs can be achieved with combination of alpha and different beta values

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| Company | Comments |
| Sony | Alpha factor determines how much of PUSCH resources can be used for UCI. Here it should depends on whether the UCI is LP or HP since we do not want a HP PUSCH to use up too much resources for a LP UCI. Threfore, we should have separate alpha values for the different UCI priorities. |
| Samsung | Yes  Separate configurations of alpha values can provide additional flexibility. Alpha is used to control the ratio of UCI to UL data. This ratio can be different for LP and HP UCI on a same PUSCH. |
| DOCOMO | We are also supportive for separate alpha values to guarantee HP PUSCH reliability. |
| InterDigital | Same reason as for beta offset. |
| CMCC | Alpha is used to limit the number of resource elements assigned to UCI on PUSCH, so smaller alpha may be expected for LP HARQ-ACK multiplex on HP PUSCH to ensure that enough resources are reserved for HP PUSCH, while for HP HARQ-ACK multiplex on HP PUSCH, both the reliability of HP HARQ-ACK and HP PUSCH needs to be guaranteed. Therefore, different alpha values need to be configured. |
| NEC | We support separate configurations of alpha values for different UCI/PUSCH combinations. |
| Intel | No  We do not think separate configuration for alpha is strictly needed. Number of REs can be flexibly controlled by choosing separate beta offsets, for a given alpha. |
| QC | Separate alpha value for HP and LP PUSCH looks reasonable. |

#### 1st round proposal and discussion

Potential proposal 3.2.3:

For HARQ-ACK/UCI multiplexing on PUSCH,

* Support separate configurations of alpha values for multiplexing with different priority combinations.

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## Other separate configurations?

* Higher layer parameter *scaling* in the *UCI-OnPUSCH* IE
  + CATT

## Conditions for multiplexing

## Whether to support multiplexing in case a PUCCH/PUSCH overlaps with more than one PUCCH/PUSCH

* Support
  + E///, ~~Samsung~~, ZTE, CMCC, Intel, LG, Sharp, DCM, NEC

**Is it related to multiplexing between two PUCCH/PUSCH?**

* Leave this question open before the UCI multiplexing rule for two overlapping PUCCHs is clear.
  + HW
* RAN1 needs to take the cases of more than two overlapping channels (involving at least one PUSCH) of different priorities into account when deciding whether to support certain multiplexing enhancements in first place.
  + This is specifically of importance when considering the support of multiplexing of high-priority UCI on low-priority PUSCH.
  + Nokia

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| Company | Comments |
| LG | Support of the multiplexing is preferred (as added in the above). We are understanding this case is differentiated from the issue 3.3.3 below, in terms of whether the overlapping channels are all within a same time unit (all are within a same slot or sub-slot in this case). |
| Sony | We support more than one PUCCH/PUSCH multiplexing but agree with HW that we should consider this when the multiplexing rules for one pair of colliding PUCCH/PUSCH is clear. |
| Sharp | This is a valid problem esp. for HP HARQ-ACK multiplexing on LP PUSCH.  It is better to consider this issue on the design of UCI multiplexing, esp. on the multiplexing location, e.g. starting symbol, and latest symbol, etc. |
| Samsung | The proposal is not clear to us.  Multiplexing of a PUCCH overlaps with more than one PUCCH is discussed under 2.2.2. This case should be excluded under this issue.  Multiplexing in case a PUCCH overlaps with more than one PUSCH is supported in Rel-15 and Rel-16, no need further discussion.  Multiplexing in case a PUSCH overlaps with more than one PUSCH should not be supported.  Multiplexing in case a PUSCH overlaps with more than one PUCCH may depends on the order of MUX. |
| DOCOMO | We prefer to support it but it should be discussed after single PUCCH/PUSCH collision case. |
| InterDigital | Support the scenario of multiplexing 2 PUCCHs and 1 PUSCH. This is already agreed since we have agreed on e.g. scenario HP HARQ-ACK + LP HARQ-ACK + LP PUSCH. |
| NEC | We support multiplexing in case a PUCCH/PUSCH overlaps with more than one PUCCH/PUSCH if the requirements of HP data/UCI can be met. |
| Intel | Support the scenario. RAN1 needs to identify suitable UE behavior. Some of the cases are already agreed as InterDigital mentioned |

ZTE proposal:

***Proposal 7:*** *For the overlapping between more than two PUCCH with different priorities and low/high priority PUSCH,*

* *the UE first resolves overlapping channels between the same UCI type, e.g., high priority HARQ-ACK and low priority HARQ-ACK,*
* *then resolves overlapping channels between UCI and low/high priority PUSCH if the overlapping still exists after overlapping processing between the same UCI type.*

Intel proposal:

*Proposal 11: If a PUSCH overlaps with two sub-slot based PUCCHs, multiplex the UCIs from the PUCCHs onto the PUSCH if timeline conditions are met. If timeline conditions are not met, drop the low priority channel and transmit the high priority channel.*

* *FFS: whether to apply Rel16 intra-UE prioritization in this case.*

*Proposal 12: If a PUCCH overlaps with two PUSCHs, following behaviors can be considered, assuming timeline conditions are met:*

* *If PUCCH is of high priority, PUCCH is multiplexed onto first PUSCH.*
* *If first (second) PUSCH is of high (low) priority, UCI from PUCCH is multiplexed onto second PUSCH if the PUCCH is of low priority.*

*Proposal 13: If a PUSCH overlaps with a PUCCH repetition in a slot, multiplex the UCI onto the PUSCH and drop the PUCCH repetition.*

* *FFS whether this is only applicable if PUSCH is of high priority and/or PUCCH is of low priority.*

## Timeline requirements

* Option 1: Reuse R15 timeline (or as the starting point)
  + HW, vivo, CATT, Nokia, IDC, QC, Xiaomi, CMCC, Sharp
* Option 2: New timeline requirement
  + DCM

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| Company | Comments |
| Sony | We should at least meet Rel-15 timeline, i.e. use this as starting point. |
| Sharp | The Rel-15 timeline can be the start point to determine the starting symbol for UCI multiplexing on PUSCH. |
| Samsung | TBD |
| DOCOMO | We prefer to define new timeline requirement as presented in 2.2.3 for more possibility of multiplexing, which would lead to better eMBB performance. |
| InterDigital | Option 1. |
| Intel | Option 1 as starting point |
| TCL | Option 1 |
| QC | Reuse Rel-15 timeline can be reused here, because Rel-15 timeline is defined with respect to UL and DL processing capabilities, which is transparent/orthogonal to what priorities of the channels are. Adding two different priorities into the multiplexing scenario does not impact the decision on timeline. |

#### 1st round proposal and discussion

Potential proposal 3.3.2:

For multiplexing UCIs of different priorities in a PUSCH in R17,

* Reuse R15 timeline as the starting point.
* FFS additional conditions.

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## Whether to support multiplexing in a PUSCH not confined within a sub-slot

* Multiplexing of HARQ-ACK on PUSCH resource only if the PUSCH resource is contained within the sub-slot configured for the HARQ-ACK which would multiplex with the PUSCH.
  + CATT, LG

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| Company | Comments |
| LG | We also prefer to allow multiplexing of HARQ-ACK on PUSCH resource only if the PUSCH resource is contained within the sub-slot configured for the HARQ-ACK. |
| Samsung | Multiplexing in a PUSCH not confined within a sub-slot is supported in Rel-16. |
| InterDigital | It depends on the priorities of HARQ-ACK and PUSCH. If the HARQ-ACK is LP, multiplexing on PUSCH may be allowed. |
| TCL | We support multiplexing in a PUSCH not confined within a sub-slot. |
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## Details for multiplexing schemes

## How to encode the UCIs with different priorities (e.g. separate coding vs. joint coding)

* Option 1: Separate coding
  + HW, Nokia, NEC, Intel, WILUS, LG, Sharp, Samsung, DCM ,CMCC, NEC
  + Arguments:
    - Match different reliability requirements to different maximal coding rate.
    - Separate beta-offsets are supported for different priority combinations.

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| Company | Comments |
| LG | We also prefer separate coding (as added in the above). |
| Sony | Separate coding. |
| Sharp | Separate coding |
| Samsung | Support Option 1. |
| DOCOMO | Support Option1. |
| InterDigital | Option 1 as baseline. |
| NEC | Support Option 1. |
| Intel | Option 1 |
| QC | Same reason as we expressed in Section 2.3.1, we disagree with separate encoding and prefer joint encoding with compression of LP UCI. |

IDC proposal:

*Proposal 6: For the scenario of low-priority and high-priority HARQ-ACK multiplexed in PUSCH, RAN1 supports solution that allows for PUSCH decodability if one HARQ-ACK codebook has less than 2 bits and the UE misses the corresponding DL assignment*.

#### 1st round proposal and discussion

Potential proposal 3.4.1:

For multiplexing UCIs of different priorities in a PUSCH in R17,

* Support separate coding for the UCIs with different priorities.

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## How to guarantee the target code rate (e.g. payload control, multiplexing priority, LP HARQ-ACK compression/compaction)

* Option 1: Different beta-offset/alpha values. Then (partly or fully) dropping, bundling/compression /compaction LP UCI can be considered if no enough resource is left.
  + HW, vivo, LGE, Apple, OPPO, NEC, Intel, Sharp, DCM

Other enhancements:

QC proposal:

*Proposal 1: Study modulation order and code rate selection for UCI multiplexed on PUSCH based on beta scaled spectrum efficiency of UCI.*

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| Company | Comments |
| Sony | We support Option 1. Details of LP UCI reduction can be FFS. |
| Sharp | We are fine with Option 1. |
| Samsung | Support dropping.  Regarding bundling/compression /compaction LP UCI, there can be quite a lot of spec work and should be of low priority. |
| InterDigital | Option 1 is ok but not sufficient for the case of multiplexing on LP PUSCH. There also needs to be sufficient resource allocated to HP UCI to ensure reliability. If allocation is capped by the “alpha” term, reliability is not met and LP PUSCH should be dropped. |
| Intel | Option 1. Partial or full dropping can be considered if sufficient resource is not available. |
| QC | The direction of Option 1 in general seems fine. But we’d like to see a more concrete proposal. |
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IDC proposal:

*Proposal 5: For multiplexing UCI of high-priority over PUSCH transmission of low-priority:*

* *Multiplexing can only occur if the number of modulated symbols Q’ for the high-priority UCI is below the limit set by alpha parameters.*

ETRI proposal:

*Proposal 9: For HARQ-ACK codebook construction, sub-slot based HARQ-ACK codebooks are concatenated, and can be transmitted for either PUSCH or PUCCH.*

*Proposal 10: DL-DCI for HP UCI which is received after UL-DCI for LP TB may affect the PUSCH mapping.*

*Proposal 11: HP UCI may not be mapped at the second hop of the PUSCH.*

*Proposal 12: Further study how to adjust the power of PUSCH for payload from the other priority.*

## How to minimize impact on the latency for high-priority HARQ-ACK

* Option 1: Multiplexing is only allowed when the ending symbol of the PUSCH (or the ending symbol of REs carrying HP HARQ-ACK on PUSCH) is no later than the ending symbols of PUCCHs carrying HP HARQ-ACK
  + HW, ZTE, OPPO, ITRI, Sharp, NEC
* Option 1a: The latency requirement can be defined as the ending symbol of PUSCH resource for multiplexed UCI transmission is not later than X symbols after the ending symbol of PUCCH for the higher priority UCI. FFS value of X.
  + CATT, CMCC, LG

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| Company | Comments |
| LG | We prefer Option 1a (as added in the above). We think Option 1 which always requires early ending of multiplexed PUSCH than HP PUCCH, would force unnecessary tight requirement in some cases. |
| Sony | Option 1 is fine. |
| Sharp | We prefer option 1 as a condition to determine the UCI multiplexing location. |
| Samsung | Not support both options  The latency can be controlled by gNB scheduling. E.g., dynamic indication of MUX.  Option 1 is not reasonable. HARQ-ACK is mapped around DMRS. If only a few symbols are used for the HP HARQ-ACK, option 1 is too restrictive.  Option 2 will bring quite a lot of spec work. E.g., X for different SCS considering PDCCH, PUSCH, PUCCH for both priorities. |
| DOCOMO | Same comment as in 2.3.4. Slightly prefer Option 1a but this could be discussed with the timeline in 3.3.2. |
| InterDigital | Option 1 as baseline |
| NEC | We prefer option 1 |
| Intel | Agree that Option 1 can be too restrictive. Either Option 1a or it can be left upto gNB implementation/scheduling decision without capturing any conditions in specifications. |
| TCL | Option 1 |
| QC | Similar to our opinion for UCI multiplexing on PUCCH, we think option 1 and 1a are very similar. A WF can be formulated based on the commonality of the two schemes. For example, in option 1a, if X=0, then it seems automatically reduced to option 1. In other words, option 1 seems a special case of option 1a. |

## Explicit indication for enabling multiplexing

* Option 1: Support explicit indication. Multiplexing is only supported when the latency impact to HP transmission is tolerable.
  + Option 1a: By beta\_offset (e.g. beta=0 to disable mux)
    - E///, Nokia, DCM
  + Option 1b: By new DCI field
    - CATT, ETRI (RRC+DCI)
  + Option 1c: By RRC configuration for CG PUSCH or HARQ-ACK corresponding to SPS PDSCH
    - Nokia, ETRI (when no DCI indication)

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| Company | Comments |
| Sony | Option 1a for LP UCI mux into HP PUSCH. For HP UCI mux into LP PUSCH, beta-offset=0 does not work as this would result in HP UCI being dropped. |
| Samsung | Support Option 1. |
| DOCOMO | Support Option 1a and open to discuss other options like RRC configuration. |
| InterDigital | Option 1a in case of HP PUSCH |
| Intel | Support Option 1. Further details can be discussed later. |
| TCL | Option 1, and the details could FFS. |
| QC | RRC configuration to enable/multiplexing has to be there as a baseline. This is not just for CG and DL SPS, but also for DG PDSCH and DG PUSCH. The reason is because: for fallback DCI, or for UE just go through initial access where the size of non-fall back DCI is not configured yet, the dynamic indication (either option 1a or option 1b) can not work.  The situation is similar to the discussion of semi-static beta configuration vs dynamic beta indication in Rel-15. Semi-static beta configuration has be introduced as a baseline because the system has to work when dynamic beta indication is not available.  So, we should agree on semi-static enabling of multiplexing between HP/LP first. Then we discuss if dynamic enabling of this feature is needed. |

WILUS proposal:

*Proposal 7. In case of HP-PUSCH or LP-PUSCH contains LP-A/N and HP-A/N, RAN1 studies how to indicate the presence of LP-A/N and/or HP-A/N to be multiplexed and “beta offset” for LP-A/N and/or HP-A/N.*

#### 1st round proposal and discussion

Potential proposal 3.4.4:

For HARQ-ACK/UCI multiplexing on PUSCH in R17,

* Support a mechanism for gNB to enable/disable the multiplexing.
  + FFS the type of the mechanism, e.g. DCI field, RRC configuration, beta\_offset=0
  + FFS other details.

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## Multiplexing rule and order

Nokia proposal:

*Proposal 3.16: RAN1 should discuss multiplexing order after Rel-16 UE behavior is clarified (still under discussion in Rel-16 maintenance work)*

LGE proposal:

*Proposal #11: Consider to keep the reserved HARQ-ACK REs for same priority with PUSCH in case of piggybacking HARQ-ACK on PUSCH for different priority.*

*Proposal #12: Consider the mapping of HP HARQ-ACK starting from the first symbol in LP PUSCH with consideration of latency requirement for HP UCI.*

Lenovo/Moto proposal:

*Proposal 4: Consider supporting repetitions of high priority UCI such as HARQ-ACK in low priority PUSCH to ensure both the low-latency and high reliability requirements.*

*Proposal 5: Support configuring more than one scaling value for the variable , to allocate different maximum numbers of resource elements to UCI with different priorities.*

*Proposal 6: UCI with different priorities are separately encoded and rate-matched.*

Spreadtrum proposal:

*The dropping rule should follow low priority->high priority with different priorities, and follow CSI->SR->HARQ-ACK with same priority.*

QC proposal:

*Proposal 7: When low priority HARQ-ACK overlap with high priority PUCCH/PUSCH, bundle the low priority HARQ-ACK codebook into X bits (e.g. X=1), append the X bits to the end of high priority HARQ-ACK codebook (if exist) and jointly encode them, and further multiplex the jointed encoded codeword on an overlapping high priority PUSCH (if exist).*

*Proposal 8: When high priority HARQ-ACK overlap with low priority PUSCH, high priority HARQ-ACK is multiplexed on low priority PUSCH by puncturing the low priority PUSCH.*

Intel proposal:

*Proposal 6: CG-UCI is regarded as high priority and can be multiplexed in a similar manner as HP HARQ-ACK onto PUSCH.*

*Proposal 7. If both HP and LP HARQ-ACK are to be multiplexed onto CG-PUSCH that includes CG-UCI, CG-UCI is jointly encoded with HP HARQ-ACK with same beta offset.*

# PHY prioritization between DG and CG PUSCHs with different priorities

## Agreements and discussion status in previous meetings

In Rel-16, it was agreed in the RAN1 #98b meeting that the HP PUSCH can puncture the LP PUSCH. However, this agreement was re-discussed in the RAN1 101-e meeting, and only the prioritization of two CG PUSCHs with different priorities was agreed while there was no consensus on the prioritization of DG PUSCH and CG PUSCH with different priorities. In the RAN1 #101-e meeting, the following proposals are provided.

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| **Proposal from Feature Lead**   * For collision handling between high priority CG and low priority DG, down-select following options.   + Option 1: define a UE capability for collision handling between the CG and DG with different priorities in PHY layer.     - If UE supports the capability, PHY layer can make the prioritization so that the UE is expected to transmit the PUSCH corresponding to the configured grant, and cancel the PUSCH transmission scheduled by the PDCCH at latest starting at the first symbol of the PUSCH corresponding to the configured grant.     - Otherwise, MAC layer should make the prioritization so that only one MAC PDU is delivered to PHY layer.   + Option 2: re-use Rel.15 timeline, MAC layer should make the prioritization so that only one MAC PDU (e.g. the one with higher priority) is delivered to PHY layer.     - Supported by QC, Intel, LG, Apple   + Option 3: PHY layer can make the prioritization so that the UE is expected to transmit the PUSCH corresponding to the configured grant, and cancel the overlapping low priority PUSCH scheduled by the PDCCH at latest starting at the first symbol of the PUSCH corresponding to the configured grant.     - Supported by Nokia, NSB, Huawei/HiSilicon, CATT, NEC, MTK, ZTE * No PHY collision handling necessary if MAC does not generate a PDU for the CG. * PHY does not expect MAC to generate a PDU for a later, lower-priority, CG PUSCH, which overlaps with an earlier, higher-priority, DG PUSCH.   **Proposal from Feature Lead**   * For collision handling between high priority DG and low priority CG, down-select following options:   + Option 1: Define a UE capability for collision handling between the CG and DG with different priorities in PHY layer.     - If a UE supports the capability, the UE is expected to cancel the overlapping low priority CG by the first overlapping symbol at the latest. Further, a UE expects that the first [overlapping] symbol of the high priority DG is not earlier than Tproc,2+d1 after the last symbol of the PDCCH with the DCI format scheduling the high priority DG.     - Otherwise, the UE can only cancel the entire PUSCH transmission corresponding to the configured grant starting in a symbol 𝑗, if the end of symbol 𝑖 for PDCCH scheduling the PUSCH is at least 𝑁2 symbols before the beginning of symbol 𝑗.   + Option 2: Rel.15 timeline is reused to support cancellation of the low priority CG PUSCH.     - A UE is not expected to be scheduled by a PDCCH ending in symbol *i* to transmit a high priority DG PUSCH on a given serving cell overlapping in time with a transmission occasion, where the UE is allowed to transmit a CG PUSCH with low priority, starting in a symbol *j* on the same serving cell if the end of symbol *i* is not at least *N2* symbols before the beginning of symbol *j*.   + Option 3: PHY layer can make the prioritization so that the UE is expected to cancel the overlapping low priority CG PUSCH by the first overlapping symbol at the latest. Further, a UE expects that the first [overlapping] symbol of the high priority DG PUSCH is not earlier than *T*proc,2+d1 after the last symbol of the PDCCH with the DCI format scheduling the high priority channel. * No PHY collision handling necessary if MAC does not generate a PDU for the CG. |

In the RAN1 #102-e meeting, the following agreement was achieved.

Agreements:

*Support PHY prioritization for the case where low-priority DG-PUSCH collides with high-priority CG-PUSCH in R17.*

* *FFS details*
* *Clarify R16 baseline if needed.*

## Solution for PHY prioritization the case where low-priority DG-PUSCH collides with high-priority CG-PUSCH in R17

**Down-select from R16 options:**

* Adopt Option 3 of R16 discussion
  + HW, vivo, E///, CATT, Samsung, Nokia, MTK, CMCC, Sharp, DCM,NEC

**Necessity of RAN1 work:**

DCM proposal:

* *No need to further discuss collision handling between DG PUSCH and CG PUSCH with different priorities as it has been resolved in Rel-16 URLLC agenda.*

Intel proposal:

*Proposal 1: PHY collision handling of low priority DG PUSCH and high priority CG PUSCH is left up to UE implementation and no RAN1 specification change is necessary.*

Apple proposal:

*Proposal 2: Clarify the Rel-16 UE behavior concerning DG/CG transmission.*

ZTE proposal:

*Proposal 8: RAN1 should clarify that for the overlapping scenario between low priority DG PUSCH and high priority CG PUSCH, the UE prioritizes the transmission with high priority index and drops the transmission with low priority index. Besides, the scheduling time of DG PUSCH need not be limited by the timeline defined in current spec.*

Xiaomi proposal:

*Proposal 7:* *The case of HP CG-PUSCH overlapping with LP DG-PUSCH should be handled by UE implementation.*

Samsung proposal:

*Proposal 8: If transmission of a CG-PUSCH with priority 1 starts after a transmission of a DG-PUSCH with priority 0 from a UE on a same serving cell and the two PUSCHs overlap, the UE is expected to cancel the DG-PUSCH before the first overlapping symbol.*

**Timeline:**

OPPO proposal:

*Proposal 6: PHY layer can make the prioritization and Rel-16 timeline is applied.*

QC proposal:

*Proposal 14: The cancellation time for CG-PUSCH and DG-PUSCH collision resolution does not reuse Rel-16 cancellation time for PUCCH/PUCCH or PUCCH/PUSCH collision.*

Sharp proposal:

*Proposal 5: For collision between a LP DG-PUSCH and a HP CG-PUSCH, the LP DG-PUSCH should be dropped before the first symbol overlapping with the HP CG-PUSCH transmission.*

* *The actual dropping time can be left as UE implementation.*

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| Company | Comments |
| Sony | We support Option 3. |
| Sharp | The current spec language can be extended to this case. Note HP CG-PUSCH transmiss occurs only if there is data in the buffer. In this case, LP DG-PUSCH can be cancelled by HP CG-PUSCH at least before the transmission of the CG-PUSCH. The exact location of dropping is up to UE implementation. |
| Samsung | Adopt Option 3 of R16 discussion |
| DOCOMO | We support to discuss the PHY prioritization so that prioritization can be done at PHY even after MAC PDUs are deliver to both UL channels. Option 3 should be adopted according to the discussion from Rel-16. |
| InterDigital | Option 3. |
| NEC | We support option 3 of Rel-16 discussion |
| Intel | Option 3 is OK and achieved by UE implementation. No RAN1 spec impact is expected since timeline cannot be established. |
| QC | We don’t support option 3. We think the timeline should be revisit because this is a PUSCH channel cancel another PUSCH channel, while the timeline in option 3 is for cancellation between PUCCH and PUSCH. |

#### 1st round proposal and discussion

Potential proposal 4.2.1:

For collision handling between high priority CG and low priority DG, down-select following options.

* PHY layer can make the prioritization so that the UE is expected to transmit the PUSCH corresponding to the configured grant, and cancel the overlapping low priority PUSCH scheduled by the PDCCH at latest starting at the first symbol of the PUSCH corresponding to the configured grant.

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## Support prioritization for the case LP CG collides with HP DG PUSCH or not?

* Support
  + Nokia, IDC, MTK, Xiaomi, CMCC, Intel, Sharp, Samsung, DCM,NEC
  + Arguments:
    - Rel-17 WI description on intra-UE multiplexing and prioritization (see below) clearly mentions that this scenario should also be specified.

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| 1. *Specify PHY prioritization of overlapping dynamic grant PUSCH and configured grant PUSCH of different PHY priorities on a BWP of a serving cell including the related cancelation behavior for the PUSCH of lower PHY priority, taking the solution developed during Rel-16 as the baseline.* |

* Not support
  + LGE, QC
  + Arguments:
    - Collision between HP CG and LP DG may not be a big issue. Collision between LP CG and HP DG could be complicated.
    - Considering URLLC requirement, it is difficult to support URLLC service via DG PUSCH due to delay from SR to UL grant and from UL grant to PUSCH, as we have been discussing.
    - Not prioritized by RAN2.

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| Company | Comments |
| Sony | Support LP CG-PUSCH & HP DG-PUSCH collision. |
| Sharp | Support this case. It can be added to the spec with minimum impact, i.e. cancel LP channel at least from the starting symbol of HP DG-PUSCH, and no early than Tproc2+d1 after the PDCCH for the HP DG-PUSCH. |
| Samsung | Support |
| InterDigital | Support. |
| NEC | Support |
| Intel | Support |
| QC | We don’t support this feature. |

Nokia proposals:

*Proposal 2.3: The Rel-16 handling of the scenarios where a dynamically scheduled high-priority channel overlaps with a low-priority channel is adopted for the scenario of overlapping between high-priority DG PUSCH and low-priority CG PUSCH.*

LGE proposals:

*Proposal #13: Consider the framework designed in Rel-10 LTE-A as the baseline for supporting simultaneous transmission of PUCCH and PUSCH in Rel-17 NR.*

*Proposal #14: Consider to introduce new timeline or offset in case of PUSCH collision handling with different priority.*

*Proposal #15: Consider enhanced collision handling between HP PUSCH and LP PUSCH with UCI piggybacking.*

*Proposal #16: PHY prioritization for the case where low-priority CG-PUSCH collides with high-priority DG-PUSCH is not supported in R17.*

IDC proposal:

*Proposal 9: When DG PUSCH of higher priority overlaps with CG PUSCH of lower priority, the UE does not expect a DG PUSCH of higher priority to start earlier than Tproc,2 + d2 symbols after the end of the last symbol of the PDCCH.*

*Proposal 10: When DG PUSCH of higher priority overlaps with CG PUSCH of lower priority, the UE cancels the transmission of the CG PUSCH before the first symbol overlapping with the DG PUSCH transmission.*

*Proposal 11: When CG PUSCH of higher priority overlaps with DG PUSCH of lower priority, the UE cancels the transmission of the DG PUSCH before the first symbol overlapping with the CG PUSCH transmission.*

MTK proposal:

*Proposal 16: The UE is expected to transmit the HP-DG PUSCH and cancel the overlapping LP-CG PUSCH. Further, the UE expects that the first overlapping symbol of the high priority DG is not earlier than Tproc,2+d1 after the last symbol of the PDCCH scheduling the HP-DG PUSCH.*

Xiaomi proposal:

*Proposal 8: In the case of LP CG-PUSCH overlapping with HP DG-PUSCH, HP DG-PUSCH will be transmitted.*

CMCC proposal:

*Proposal 14: For collision handling between high priority DG-PUSCH and low priority CG-PUSCH, UE is expected to cancel the overlapping low priority CG PUSCH by the first overlapping symbol at the latest. Further, a UE expects that the first overlapping symbol of the high priority DG PUSCH is not earlier than Tproc,2+d1 after the last symbol of the PDCCH with the DCI format scheduling the high priority channel.*

Intel proposal:

*Proposal 2. Define a new UE capability for collision handling between the LP CG and HP DG PUSCH in PHY layer.*

* *If UE supports the capability, the UE is expected to cancel the overlapping low priority CG PUSCH by the first overlapping symbol at the latest. Further, the UE expects that the first symbol of the high priority DG PUSCH is not earlier than Tproc,2+min(d1,d2) after the last symbol of the PDCCH with the DCI format scheduling the high priority DG PUSCH, where d1 and d2 can be from {0, 1, 2} symbols, and correspond to the additional margins for cancelation and preparation times respectively in case of intra-UE prioritization and reported as UE capability.*
* *Otherwise, the UE can only cancel the entire PUSCH transmission corresponding to the configured grant starting in a symbol 𝑗, if the end of symbol 𝑖 for PDCCH scheduling the PUSCH is at least Tproc,2 before the beginning of symbol 𝑗.*

Samsung proposal:

*Proposal 9: If transmission of a DG-PUSCH with priority 1 starts after a transmission of a CG-PUSCH with priority 0 from a UE on a same serving cell and the two PUSCHs overlap, a UE is expected to cancel the CG-PUSCH before the first overlapping symbol.*

#### 1st round proposal and discussion

Potential proposal 4.3.1:

Support PHY prioritization for the case where high-priority DG-PUSCH collides with low-priority CG-PUSCH in R17.

* FFS details
* Clarify R16 baseline if needed.

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# Simultaneous x-CC PUCCH/PUSCH transmissions for inter-band CA

## Agreements in previous meetings

Agreements:

*Support simultaneous PUCCH/PUSCH transmissions on different cells at least for inter-band CA.*

* *FFS how to trigger this function.*
* *FFS for intra-band CA.*

## General principle

LGE proposal:

*Proposal #13: Consider the framework designed in Rel-10 LTE-A as the baseline for supporting simultaneous transmission of PUCCH and PUSCH in Rel-17 NR.*

Nokia proposal:

*The simultaneous transmission of PUCCH and PUSCH on different serving cells is applicable for the case when PUCCH and PUSCH are of different PHY priority only.*

#### 1st round proposal and discussion

Potential proposal 5.2.1:

* Consider the framework designed in Rel-10 LTE-A as the baseline for supporting simultaneous transmission of PUCCH and PUSCH in Rel-17 NR.
* The simultaneous transmission of PUCCH and PUSCH on different serving cells is applicable for the case when PUCCH and PUSCH are of different PHY priority only.

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## How to trigger this function?

* Signaling
  + QC: RRC on per CC basis
  + E///: RRC enable + dynamically disable
  + Nokia: RRC, MAC CE or PHY signaling
  + Intel: Configured
  + OPPO: RRC for CC, and configured for HP PUCCH and LP PUCCH
  + DCM: UE capability
  + MTK:
    - separately configured for inter-band and intra-band
    - separately configured for different priorities
    - enabled based on specific conditions. E.g. LP-PUCCH carrying HARQ feedback

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| Company | Comments |
| LG | On this simultaneous PUCCH+PUSCH transmission, basically, it is preferred to inherit the framework designed in Rel-10 LTE-A in terms of feature capability/enabling (e.g. configured UE-specifically by RRC) and UCI multiplexing behavior. |
| Samsung | RRC enable + dynamically disable |
| DOCOMO | We are also supportive for RRC configuration. |
| Intel | The feature can be enabled by RRC configuration. We are also open to consider DCI based indication. |
| QC | In general, we think RRC configuration of this feature is more robust to DCI detection error/miss detection. And we don’t see much benefit to do dynamic enable/disable this feature, which seems an over-design to us. The benefit of dynamic indication is not clear to us. |
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DCM proposal:

*Proposal 7:*

* *Introduce a UE capability to trigger the simultaneous PUCCH and PUCH transmission on different carriers.*

*Proposal 8:*

* *Discuss the interaction between capabilities for two PUCCH groups and the new capability for simultaneous PUCCH/PUSCH transmission on different carriers.*

QC proposal:

*Proposal 15: The enabling/disabling of the feature of simultaneous PUCCH/PUSCH transmission for inter-band CA is via RRC configuration on per CC basis. For a CC where RRC enables simultaneous PUCCH/PUSCH transmission, this CC is dedicated to PUSCH transmission and UCI is not multiplexed on this CC.*

*Proposal 16: Support the PHR for simultaneous PUCCH/PUSCH for inter-band CA with either of the following two options.*

* *Option 1: reuse LTE type 2 PHR for PUCCH transmission on PCC with a virtual/reference PUSCH*
* *Option 2: define a type 4 PHR for PUCCH transmission on PCC*

Intel proposal:

*Proposal 14: UE can be configured to transmit low priority PUCCH (PUSCH) in one carrier and high priority PUSCH (PUCCH) in a different carrier. UE may only multiplex channels of same priority in one carrier, and transmit different priority channel(s) in another carrier.*

* *If UE is configured with both simultaneous PUSCH and PUCCH transmissions over different carriers and Rel16 or Rel17 intra-UE prioritization, option of simultaneous transmissions should take precedence over the intra-UE prioritization.*

## Support simultaneous PUSCH/PUCCH transmission for intra band CA or not?

* Support.
  + vivo (as optional UE feature), Samsung (no need to differentiate between intra-band CA and inter-band CA), MTK (for some cases), DCM
  + Arguments:
    - In NR Rel-15, multiple PUSCHs transmission on different carries and one among them with the piggy-backed UCI has been already supported for both inter band CA and intra band CA.
* Not support.
  + Nokia
  + Arguments:
    - Considering the most efficient implementation with a single PA (most likely case of intra-band CA), e.g. Tx discontinuity, Large Tx power back-off.

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| Company | Comments |
| LG | As defined in LTE-A, it is to be UE capability per band and band combination. |
| Samsung | Support |
| DOCOMO | Support |
| Intel | More careful consideration is needed before it is supported. Whether the feature is only allowed if the overlapping transmissions are fully aligned. If yes, then scope seems quite limited. |
| TCL | Support |
| QC | We are open to discuss this feature for intra-band CA. Alignment of the starting and ending of the simultaneous PUCCH/PUSCH transmission seems required in intra-band CA. |
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MTK proposal:

*Proposal 8: Support simultaneous PUCCH/PUSCH transmissions on different cells for intra-band CA for the same numerology both with aligned and non-aligned channel case.*

*Proposal 9: Support simultaneous PUCCH/PUSCH transmissions on different cells for intra-band CA for different numerology if the transmissions are aligned on symbol-level (with the symbol of the lowest SCS as a reference).*

* *i.e. Allocation on the carrier with higher numerology doesn’t start during an ongoing symbol on the other carrier with the smaller numerology.*

## Support simultaneous PUSCH/PUCCH transmission on a same cell?

* Support.
  + Samsung, Pana

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| Company | Comments |
| Samsung | Support |
| Intel | Not in scope |
| QC | We are open to discuss this. This should be carefully studied before making a decision, given that this feature was specified in LTE but never deployed. |
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Samsung proposal:

*Proposal 6: Send an LS to RAN4 to inquire about the feasibility/MPR for simultaneous PUCCH and PUSCH transmissions on a same cell.*

Panasonic proposal:

*Observation 1: Whether simultaneous PUCCH and PUSCH transmission in a carrier is useful or not should be studied.*

* *If the simultaneous transmission is restricted to adjacent or almost adjacent frequency resource, the gain would be limited.*
* *How to ensure the same transmit power for all symbols and how to handle PSD difference between PUCCH and PUSCH should be taken into account.*

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