3GPP TSG RAN WG1 #104-e R1-2101842

e-Meeting, January 25th – February 5th, 2021

Source: Moderator (OPPO)

Title: Summary#1 of email thread [104-e-NR-R17-IIoT\_URLLC-04]

Agenda Item: 8.3.3

Document for: Discussion and Decision

# Introduction

This is the summary for the following email discussion:

[104-e-NR-R17-IIoT\_URLLC-04] Email discussion on intra-UE multiplexing/prioritization – Jia (OPPO)

* 1st check point: Jan 28
* 2nd check point: Feb 2
* 3rd check point: Feb 4

# 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).*

Agreements:

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

* *Support of multiplexing between different resources not confined within a sub-slot if conditions are met*
  + *FFS: Details*
* *Support multiplexing in case a PUCCH overlaps with more than one PUCCH if conditions are met*
  + *FFS details*

Agreements:

*For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, down-select from the following options in RAN1#104-e:*

* *Option 1: Support joint coding.*
* *Option 2: Support separate coding.*
* *Option 3: Combination of Option1 and 2.*
* *FFS the details*

*For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits is 2 bits, provide design details for decision for the following cases in RAN1#104-e:*

* *Multiplexing on a PUCCH format 0*
* *Multiplexing on a PUCCH format 1*

Agreements:

*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.*

* *FFS the type of the mechanism, e.g. DCI indication and/or RRC configuration*
* *FFS: Interaction between the enable/disable mechanism and other multiplexing conditions*
* *FFS for other types of UCI.*

## Coding for UCIs with different priorities (e.g. separate coding vs. joint coding)

## Inputs from Tdocs

**When the total number of LP and HP HARQ-ACK bits is more than 2,**

* Option 1: Joint coding.
  + OPPO, MTK, Intel, Lenovo/Moto, QC
* Option 2: Separate coding. Separate maxCodeRate.
  + ZTE (if both UCIs > 2bits), HW, E///, vivo, Nokia, Spreadtrum, Sony, TCL, APT, CMCC, ETRI, Samsung, WILUS
  + Option 2a: Separately configured maxCodeRate for HP and LP HARQ-ACK.
  + Option 2b: Reuse the maxCodeRate of HP and LP HARQ-ACK configured on their original PUCCH resource.
* Option 3: Combination of Option1 and 2. Separate or joint coding depends on the payload size of LP and/or HP HARQ-ACK
  + CATT, IDC, LGE, Pana, Sharp, DCM

**When the total number of LP and HP HARQ-ACK bits is 2,**

* treat the two bits as HARQ-ACK bits with the same priority and using R15 mapping rules.
  + OPPO, HW, CATT, vivo, Intel, Nokia, LGE, Pana, Samsung

|  |  |  |  |
| --- | --- | --- | --- |
| **Analysis on Separate coding** | | | |
|  | | Arguments | Counter arguments |
| Advantages | Resource efficiency | Provide more optimized resource usage for HARQ-ACK. Avoid unnecessary dropping/compression of LP HARQ-ACK.  Joint coding cannot provide distinguished latency/reliability protections for UCIs of different priorities, thus use more resources to transmit LP HARQ-ACK with high reliability. Or, UE must either sacrifice the reliability of the HP HARQ-ACK if a high coding rate is selected.  In case the number of high-priority HARQ-ACK/UCI bits is low and the number of low-priority HARQ-ACK/UCI bits is high, which would typically be the case, joint coding may not be preferable from coding gain perspective as, in this case, the effective coding rate for high-priority HARQ-ACK/UCI would be higher compared to separate coding. | The gain is uncertain because it is related to the payload size and the maximum coding rate of HP and LP HARQ-ACK.  If the payload size of LP HARQ-ACK is less than HP HARQ-ACK, separate coding may not bring too much benefit since LP HARQ-ACK may not occupy too many resources.  There are much simpler ways to enhance the reliability when multiplexing, such as bundling, threshold on LP UCI payload, and payload compressing.  For a same effective coding rate, separate encoding has smaller coding gain than joint encoding |
| Latency | For PUCCH format 3/4, HP HARQ-ACK can be mapped on the earlier symbols with separate coding.  For joint coding, the gNB can only start the decoding procedure after it has received all symbols of the jointly coded UCI, the processing of the HP HARQ-ACK is delayed. |  |
| Robustness against DCI mis-detection | 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.  In theory, the mis-detection of low priority DCI would be more often than high priority DCI. | This is very limited corner case, and it doesn’t justify complicating the specifications and the UE implementation. The probability of missed the DCI is very low even for LP traffic (~1%). In addition, the chance of having a missed LP “last” DCI and the corresponding LP HARQ-ACK get multiplexed with HP UCI is even lower because it is expected that multiplexing between LP and HP UCIs doesn’t occur often. For example, if multiplexing between LP and HP UCIs has probability of 1%, the probability of missing LP “last” DCI and the corresponding LP HARQ-ACK get multiplexed with HP UCI will be 0.01%.  Having separate coding doesn’t resolve the issue of codebook-size ambiguity between the UE and the gNB. The LP and HP UCIs will be added together in a PUCCH resource, and that resource set is determined based on the total UCI size. Missing last DCI (LP or HP) can change the resource set and separate encoding doesn’t resolve the issue. |
| Problems | Coverage gain |  |  |
| Standardization efforts | * New procedures need to be defined to signal multiple coding rates for HP and LP HARQ-ACK on PUCCH: for one PUCCH resource, need signal one code rate for LP UCI and multiple code rates for HP UCI with different payload size. * New procedures need to be defined to 1) perform separate coding and modulation, 2) PUCCH resource determination, 3) RE mapping, and 4) power control | RM and Polar coding defined in TS 38.212 section 6.3.1 can be reused.  Already used in Rel-15 for CSI part-1 (with/without HARQ-ACK) and CSI part-2. |
| UE complexity | * Multiple channel encoders are required to prepare one PUCCH at the UE, which increases the implementation complexity and impacts the UE processing timeline * Separate CRC bits are used for LP and HP HARQ-ACK, which increases the effective coding rate for a fixed # resources (compared to joint encoding). |  |
| **Analysis on Joint coding** | | | |
| Advantages | Less UE complexity & standardization efforts | No need for an additional polar encoder  Rel-15 rate matching equations could be essentially re-used  More resource efficient in some cases, depending on the amount of resource and the size of each of high-priority and low-priority HARQ-ACKs.  If bundling is agreed, joint coding could provide good performance at least in most of the cases when bundling is used. |  |
| Problems | Priority protection | Joint coding cannot provide distinguished latency/reliability protections for UCIs of different priorities, thus results in either low spectrum utilization or degraded performance.  Always relying on bundling so that joint coding could be used without impacting the high-priority HARQ-ACK defies the main Rel-17 intra-UE topic objective of trying to avoid losing/dropping low-priority HARQ-ACK information whenever possible |  |

**Simulation results provided by Ericsson for the total number of LP and HP HARQ-ACK bits is more than 2:**

Figure 2 - Figure 5 of [5] show performance results for joint vs separate encoding of URLLC and eMBB HARQ feedback. We assume a BLER target of 1e-2 for eMBB HARQ feedback and 1e-5 for URLLC HARQ feedback.



Figure 2: Performance of joint vs separate coding for PUCCH Format 3 for 12 eMBB and 8 URLLC bits.



Figure 3: Performance of joint vs separate coding for PUCCH Format 3 for 12 eMBB and 12 URLLC bits.



Figure 4: Performance of joint vs separate coding for PUCCH Format 3 for 24 eMBB and 8 URLLC bits.



Figure 5: Performance of joint vs separate coding for PUCCH Format 3 for 48 eMBB and 8 URLLC bits.

**Simulation results provided by Qualcomm in case the total number of LP and HP HARQ-ACK bits is more than 2:**

Table 3. Coding rates for HP and LP UCI

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Coding scheme | # HP HARQ-ACK bits | # LP HARQ-ACK bits | Coding rate for HP HARQ-ACK | Coding rate for LP HARQ-ACK |
| Separate encoding | 1 | 8 | 0.04 | 0.17 |
| Joint encoding | 1 | 8 | 0.125 | |
| Joint encoding with LP HARQ-ACK compression | 1 | 4 | 0.07 | |

The simulation results are shown in the figure below. Not surprisingly, separate encoding is indeed able to provide better protection to the HP HARQ-ACK. However, we also see that joint encoding with compression factor 2 for the LP HARQ-ACK is able to outperform the separate encoding scheme for both the HP and LP HARQ-ACK. This is mainly due to the coding gain achieved by joint encoding compared to the simple repetition applied on the HP HARQ-ACK in the separate encoding case.



**Fig 8: Performance comparison between separate encoding and joint encoding for 1 bit HP HARQ-ACK multiplexing with 8 bits LP HARQ-ACK on a PUCCH**

**Simulation results provided by Qualcomm in case the total number of LP and HP HARQ-ACK bits is 2:**

Based on the simulation results as shown in **Fig 7**, we can see the Rel-17 proposal can offer 2~3 dB gain over Rel-15 baseline, either with the TDM version or non-TDM version. The reason Rel-17 proposal performs better than Rel-15 baseline non-TDM version is because the QPSK modulation breaks the orthogonality between the 4 transmission signals/hypotheses, as explained above by the cross-correlation result. The reason Rel-17 proposal performance better than the Rel-15 baseline TDM version is because TDM resulting transmission of each bit with less OFDM symbols.

Chart

Description automatically generated

Chart

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**Fig 7: Performance comparison between Rel-17 proposal and Rel-15 PF1 baseline (w/ TDM or w/o TDM)**

|  |  |
| --- | --- |
| Company | Proposals/observations from Tdocs |
| ZTE | ***Observation 1:*** *The separate coding with different coding rate is beneficial for saving resource when the two UCIs with different priorities will be transmitted in a same PUCCH.*  ***Proposal 2:*** *Adopt separate coding for the multiplexing of high priority UCI and low priority UCI on a PUCCH format 2/3/4 except the payload of one of the UCIs is no more than 2 bits.*  ***Proposal 3:*** *When the two UCIs with different priorities will be multiplexed on a PUCCH format 2/3/4 by separate coding, for a certain priority UCI,*   * *If its number of bits is more than 2 bits but no more than 11 bit, RM coding is performed for this UCI.* * *If its number of bits is more than 11 bits, Polar coding is performed for this UCI.* |
| OPPO | ***Proposal 5: Joint coding is used to support the multiplexing of HP HARQ-ACK and LP HARQ-ACK in one PUCCH with more than 2 HARQ-ACK bits.***  ***Proposal 6: No enhancement is supported for multiplexing of 1-bit HP HARQ-ACK and 1-bit LP HARQ-ACK on a PUCCH format 0/1.*** |
| Huawei | ***Proposal 1: For multiplexing high-priority HARQ-ACK and low-priority HARQ-ACK on PUCCH in case that the total number of bits is 2 bits, the 1-bit high-priority HARQ-ACK and the 1-bit low priority HARQ-ACK are concatenated and transmitted on PUCCH format 0 or PUCCH format 1 following the existing mechanism.***  ***Proposal 2: For multiplexing high-priority HARQ-ACK and low-priority HARQ-ACK on PUCCH in case that the total number of bits is more than 2, separate coding is adopted.*** |
| E/// | 1. Separate coding shows a gain over joint coding when the number of URLLC bits is small. A proper split of radio resources is needed to maximize gain.   Proposal 7 Support separate encoding of high and low priority HARQ feedback in a PUCCH resource. |
| CATT | ***Proposal 4: For multiplexing of HP HARQ-ACK and LP HARQ-ACK when total number of bits is 2, 1 bit HP HARQ-ACK and 1 bit LP HARQ-ACK are transmitted on the time-frequency resource for the HP HARQ-ACK transmission as below:***   * ***If PUCCH format 0 is used for HP HARQ-ACK, sequence cyclic shifts as shown in the table below are used***  |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | **Sequence cyclic shift** |  |  |  |  |  * ***If PUCCH format 1 is used for HP HARQ-ACK, 2 bits are modulated into a modulation symbol and transmitted on PUCCH resource for HP HARQ-ACK.***   ***Proposal 6: For multiplexing of HP HARQ-ACK and LP HARQ-ACK when total number of bits is more than 2, combination of joint coding and separate can be supported.***  ***Proposal 7: The following two options can be considered to avoid the impact on HP HARQ-ACK(s) due to missing DCIs corresponding to LP HARQ-ACK codebook.***   * ***Option 1: Define a reference number of bits for LP HARQ-ACK codebook*** * ***Option 2: Indicate information for determine the number of LP HARQ-ACK bits by DCI corresponding to HP HARQ-ACK*** |
| vivo | ***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.***  ***Proposal 4: For UCI transmission multiplexed on PUCCH with different priorities, separate coding can be supported.***  ***Proposal 5: If joint coding is adopted, the maximum number of LP UCI should be limited to X bits.***   * ***X can be configured by gNB.*** * ***If LP UCI is more than X bits, the method to obtain X bits can be FFS.***   ***Proposal 8:*** ***For multiplexing a HP HARQ-ACK and a LP HARQ-ACK, when the total number of LP and HP HARQ-ACK bits is 2 bits***   * ***On PUCCH format 0: HP HARQ-ACK bit and LP HARQ-ACK bit are mapped into a*** ***cyclic shift as in R15/R16*** * ***On PUCCH format 1: HP HARQ-ACK bit and LP HARQ-ACK bit are modulated into a QPSK symbol as in R15/R16*** |
| MTK | 1. Joint coding is used for multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH, when the total number of LP and HP HARQ-ACK bits are more than 2 bits. |
| Intel | **Proposal 3: Support joint coding of LP and HP HARQ-ACK payload bits when combined payload is more than 2 bits.**   * **Multiplexed HARQ-ACK payloads are transmitted using PUCCH configuration of HP codebook** * **LP HARQ-ACK payload bits can be partitioned or a threshold on the payload can be considered to maintain target code rate.**    + **Dropped portion of LP HARQ-ACK payload bits can be retransmitted.**   **Proposal 4: Use Rel-15 PF0 and PF1 transmission framework as starting point for multiplexing LP and HP HARQ-ACK payload bits when total payload is 2 bits.** |
| Nokia | **Proposal 3.5: For the scenario where a PUCCH carrying high-priority HARQ-ACK overlaps with another PUCCH carrying low-priority HARQ-ACK and the total payload size is two bits, multiplexing can be done on the high-priority PUCCH resource by treating the two bits as high-priority HARQ-ACK bits and using existing rules of mapping two HARQ-ACK bits of the same priority.**  **Proposal 3.6: For the scenario where a PUCCH carrying high-priority HARQ-ACK overlaps with another PUCCH carrying low-priority HARQ-ACK, RAN1 to adopt separate encoding for the multiplexing of high-priority HARQ-ACK and low-priority HARQ-ACK.** |
| Spreadtrum | 1. ***For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH, separate coding should be supported at least.*** 2. ***If the multiplexed total number of LP and HP HARQ-ACK bits is 2 bits, multiplexing on PUCCH format 1 should be considered first.*** |
| IDC | ***Proposal 7: For channel coding when LP and HP HARQ-ACK codebooks are multiplexed, use separate coding if the LP and HP HARQ-ACK payloads are both above a minimum Nmin, otherwise use joint coding.***  ***Proposal 8: DCI indicating HP HARQ-ACK includes an indication of the DAI of LP HARQ-ACK.*** |
| Sony | **Proposal 1: The UCI bits of different L1 priorities are separately coded when multiplexing into a PUCCH and the total number of UCI bits is greater than 2.**  **Proposal 2: Allow encoded UCI bits of different L1 priorities to be mapped to different symbols in the PUCCH.** |
| LGE | **Proposal #2: Decide UCI bit mapping used for cyclic shift or QPSK modulation for multiplexing of LP UCI and HP UCI on PUCCH format 0/1 with the total UCI payload size of 2 bits.**   * **HP UCI bit and LP UCI bit are mapped to MSB and LSB, respectively.** |
| TCL | **Proposal 1: For multiplexing UCIs with different priorities on a same PUCCH, separate coding should be supported and the coding rate should be different.** |
| APT | Proposal 1 Separate coding of high priority UCI and low priority UCI when multiplexed in a PUCCH is supported as a baseline. |
| Lenovo/Moto | **Proposal 3:** Support joint encoding of HP UCI with LP HARQ-ACK, if multiplexed in PUCCH of PUCCH formats 2, 3, and 4. |
| Pana | **Proposal 4: For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, the combination of joint coding and separate coding is supported.**  **Proposal 5: For the determination of coding scheme, at least the number of HP HARQ-ACK bits and/or the number of LP HARQ-ACK bits should be considered.**  **Proposal 6: For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH, when the total number of LP and HP HARQ-ACK bits is 2 bits, LP HARQ-ACK bit is appended to HP HARQ-ACK bit and 2 bits are transmitted on PUCCH resource (PUCCH format 0 or 1) assigned for HP HARQ-ACK.** |
| CMCC | **Proposal 6: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, separate coding and mapping with different coding rates is supported.**  **Proposal 7: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits is 2 bits, which PUCCH format is used should be determined by the selected PUCCH resource.**  **Proposal 8: 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. |
| ETRI | **Proposal 5: Separate coding in one PUCCH is supported.** |
| Samsung | **Proposal 3: Support separate coding for UCIs with different priorities multiplexed on a same PUCCH format 2/3/4 or PUSCH.**  **Proposal 4: Support multiplexing 1 bit HP HARQ-ACK and 1 bit LP HARQ-ACK into a HP PUCCH resource, HP HARQ-ACK is placed before LP HARQ-ACK.**   * **For PUCCH format 0, Table 1 can be used to determine the sequences cyclic shit.** * **For PUCCH format 1, modulation of 2 bits HARQ-ACK of a same priority can be reused.**   **Table 1: Mapping of values for 1 bit HP HARQ-ACK and 1bit LP HARQ-ACK to sequences for PUCCH format 0**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | **Sequence cyclic shift** |  |  |  |  | |
| QC | ***Proposal 2*: For 1-bit high priority HARQ-ACK and 1-bit low priority HARQ-ACK transmitted in a PUCCH format 0 resource, support HARQ-ACK values to CS indices mapping with unequal distance between mapped CS indices.**   * **FFS: Solution for 1-bit HP HARQ-ACK and 1-bit LP HARQ-ACK multiplexing with 1-bit HP or LP SR on PUCCH format 0**     ***Proposal 3*: For 1-bit high priority HARQ-ACK and 1-bit low priority HARQ-ACK transmitted in a PUCCH format 1 resource, support transmit the 2-bits HARQ-ACK values via two orthogonal sequences S1 and S2.**   * **S1 and S2 are generated based on the same base sequence S with different CS indices CS1 and CS2.** * **1-bit is transmitted via sequence selection between S1 and S2, while the other bit is transmitted using the selected sequence following legacy Rel-15 PF1 with 1-bit payload.** * **gNB can signal either HP 1-bit or LP 1-bit is transmitted via sequence selection.**   **FFS: Solution for 1-bit HP HARQ-ACK and 1-bit LP HARQ-ACK multiplexing with 1-bit HP or LP SR on PUCCH format 1**  ***Proposal 4*: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, support joint coding of the HP and LP HARQ-ACK, with LP HARQ-ACK compressed prior to joint encoding.**   * **FFS how to compress the LP HARQ-ACK prior to joint encoding.** |
| Sharp | **Proposal 3: For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH,**   * **When the total number of LP and HP HARQ-ACK bits is 2 bits, the LP-HARQ-ACK is appended to HP HARQ-ACK, and the concatenated HARQ-ACK bits are reported on the original PUCCH resource for the HP HARQ-ACK with PF 0 or 1.** * **When the total number of LP and HP HARQ-ACK bits is 2 bits, a HP HARQ-ACK PUCCH resource with PF 2/3/4**    + **Joint coding or separate is determined based on a payload threshold**   + **In case of separate coding. code rate for HARQ-ACK with different priorities are determined based on existing or additional configured maxCoderate parameters.** |
| DCM | **Proposal 1:**   * *Support Option 3 (i.e. combination of separate coding and joint coding) for encoding scheme for combined UCI bits in case the total number of LP and HP HARQ-ACK bits are more than 2 bits.*   + *The condition to determine coding scheme can be LP UCI payload size.*   **Proposal 2:**   * *For separate coding, a scaling factor can be introduced for HP and LP UCI coding rate determination.*   **Proposal 3:**   * *For separate coding, an effective UCI payload size is introduced for PUCCH resource selection and PRB determination procedure, where is determined by HP UCI payload size, LP UCI payload size, HP UCI coding rate for multiplexing, LP UCI coding rate for multiplexing, and also additional CRC bits introduced by separate coding.* |
| WILUS | * ***Proposal 1: We propose to configure two maximum code rates per PUCCH format, one for LP-UCI and the other for HP-UCI.*** * ***Proposal 3: We propose to support the separate encoding for multiplexing two priorities.*** |

## 1st round proposal and discussion

Proposal for 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits,

* Support separate coding if the payload size of LP HARQ-ACK and/or HP HARQ-ACK is larger than a value.
* Support joint coding if the payload size of LP HARQ-ACK and/or HP HARQ-ACK is smaller than a value.
* FFS for other UCIs

Proposal after 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, down-select from the following options

* Option 1: Joint coding with compression for the LP HARQ-ACK.
  + QC, OPPO, Intel, ITRI, Lenovo/Moto, NEC
* Option 2: Separate coding. Separate maxCodeRate.
  + Nokia, Samsung, Sony, E///, WILUS, HW, ETRI, APT
* Option 3: Separate coding and joint coding are both supported under some condition.
  + The condition is about HARQ-ACK payload size
    - FFS the condition is related to HP or LP HARQ-ACK payload size, or both.
    - FFS details of the condition.
  + DCM, Samsung, Pana, IDC, Sharp, CATT, vivo, LG, WILUS, Spreadtrum, NEC, APT

Proposal for 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits is 2 bits, treat the two bits as HARQ-ACK bits with the same priority and using R15 mapping rules.

* FFS for other UCIs

Proposal after 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits is 2 bits,

* For multiplexing on a PUCCH format 0, down-select from following options:
  + Option 1: Treat the two bits as HARQ-ACK bits with HP priority and using R15 mapping rules.
  + Option 2: Support HARQ-ACK values to CS indices mapping with unequal distance between mapped CS indices.
* For multiplexing on a PUCCH format 1, down-select from following options:
  + Option 1: Treat the two bits as HARQ-ACK bits with HP priority and using R15 mapping rules.
  + Option 2: Support transmit the 2-bits HARQ-ACK values via two orthogonal sequences S1 and S2.
    - S1 and S2 are generated based on the same base sequence S with different CS indices CS1 and CS2.
    - 1-bit is transmitted via sequence selection between S1 and S2, while the other bit is transmitted using the selected sequence following legacy Rel-15 PF1 with 1-bit payload.
      * gNB can signal either HP 1-bit or LP 1-bit is transmitted via sequence selection.

|  |  |
| --- | --- |
| Company | Comments |
| DOCOMO | Agree with the first proposal for the case where the total number of LP and HP HARQ-ACK bits are more than 2 bits.  For the second proposal, we are fine with the proposal in general but it should be clarified that both HP and LP HARQ-ACK are treated as ‘HP’ and multiplexed on the HP PUCCH resource using R15 mapping rules. Thus we propose the following modification:  Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits is 2 bits, treat the two bits as HARQ-ACK bits ~~with the same priority~~ HP and multiplexed on HP PUCCH resource using R15 mapping rules.  FFS for other UCIs |
| QC | We disagree with both above proposals.  The main concern we have is that, the design principle of 2 bits and >2 bits are contradict to each other. With >2 bits, people care about HP bits and want separate coding to protect HP bits. But then with 2 bits, people suddenly don’t care about reliability of HP and the proposal is reuse Rel-15 which CANNOT offer HP bit with more reliable performance. To me, 2 bits is the most important scenario for intra-UE mux. It could happen quite often that gNB schedules a later URLLC PDSCH whose 1 bit HARQ-ACK overlaps with 1 bit HARQ-ACK of a previous scheduled eMBB PDSCH. How come we suddenly don’t care about the HP HARQ-ACK and essentially treat it the same as low priority? It does not matter you put it in HP or LP PF0/1 resource. Rel-15 baseline cannot offer better performance for HP bit over the LP bit.  We strongly urge RAN1 to adopt a single principle for 2 bits and >2 bits. If we want different reliability between HP and LP HARQ-ACK via separate coding for >2 bits, we should seek solution can offer different reliability for 2 bits case too. If we don’t care about different reliability between HP and LP HARQ-ACK, then joint encoding is the way to go, because it is much simply than separate encoding. We suggest FL leads a discussion to settle down a **unified** design principle first. For us, we are open to either way. We just cannot accept contradicting design principles for these two cases.  As for the current proposal, for 2 bits case, like mentioned above, the current proposal CANNOT offer more reliable performance for HP bit. On the other hand, we have proposals (for both PUCCH format 0 and 1) that can improve HP bit significantly than the current proposal. Our proposal and simulation results are missed in FL summary. Therefore, we copy our main proposal and results below. Without technical discussion, we are not OK to agree the current proposal for 2 bits case.  For 2 bits on PF0, by simply use unequal distance CS mapping (See figure below), at least 1.5 dB gain can be achieved (see figures below). The spec impact and impact to gNB receiver is very small. But the scheme can provide HP HARQ-ACK better by 1.5dB. We should discuss and study the scheme vs Rel-15 baseline, before jumping to the conclusion to use Rel-15 baseline.      For PF1, we have a proposal which can offer at least 2.5dB gain for HP bit over the Rel-15 baseline. The proposal is to do resource selection for HP and LP bit, similar to Rel-15 SR+PF1-HARQ-ACK resource selection. Again, the impact to receiver is very small, because Rel-15 already support SR+PF1-HARQ-ACK multiplexing.    Chart  Description automatically generated  For >2 bits case, thanks Ericsson to provide simulation results to evaluate joint vs separate coding. But we also provided simulation results in our contribution. Unfortunately, our result is not captured in the FL summary. So we copy it below. Our result shows that applying 50% compression/bundling to LP bits, joint encoding outperforms separate encoding. |
| Nokia/NSB | - Do not support the first proposal.  We prefer to adopt a single coding approach, i.e. down-select between either separate or joint coding. Actually, specifying both approaches and defining a ‘value’/threshold, or more generally the conditions, to decide which approach to use at a given instance would potentially require a lot of discussions.  Our preference, which is shared by the majority of companies, is to support separate coding for the reasons we listed in our contribution (R1-2100729).  - Support the second proposal in principle.  The intention of the FFS point, which generally talks about UCI under a specific proposal on HARQ-ACK, is not clear to us. |
| OPPO | - Do not support the first proposal.  Compared with joint coding, for some cases, separate coding may save physical resources and avoid the dropping/compression of LP HARQ-ACK. However, the gain of separate coding, related to the payload size and the maximum coding rate of HP HARQ-ACK and LP HARQ-ACK, is uncertain. On the other hand, spec effort is large, at least the following issues have to be specified to support option 2:   * 1. The procedures for determining PUCCH PRB number   2. The procedures for physical resource mapping, e.g. RE or PRB mapping   3. The procedures for determining code rate for HP HARQ-ACK and LP HARQ-ACK in one PUCCH resource   From perspective of system efficiency, we share view with QC, HARQ-ACK compression/bundling is more effective than separate coding. Moreover, HARQ-ACK compression/bundling is a traditional solution, which has been supported in LTE. The spec effort is smaller.  From perspective of reliability, separate coding only is not enough to ensue reliability for HP HARQ-ACK either. To ensure reliability of HP HARQ-ACK, separate mapping is deserved to discuss firstly rather than separate coding.  -Support the second proposal. |
| ZTE | For the first proposal, we support separate coding for the two HARQ-ACK generally. We think the concern on the gain of separate coding is valid when the payload of low priority HARQ-ACK is too small because the cost of CRC overhead for low priority HARQ-ACK can’t balance the gain. Besides, the coding and mapping rules of a UCI with no more than 2 bits transmitted in the PUCCH is not support in current spec. Therefore, it is reasonable to adopt separate coding only when both of payload of the two HARQ-ACKs are more than 2 bits, otherwise the joint coding is preferable.  We are fine with the second proposal. |
| Samsung | Support the proposals in principle.  For the first proposal, our first preference is to support separate coding. As a compromise, we are fine to support separate coding if the payload size of LP HARQ-ACK is larger than a value. The payload size of HP HARQ-ACK should not be involved. We suggest the following update.  Updated Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits,   * Support separate coding if the payload size of LP HARQ-ACK ~~and/or HP HARQ-ACK~~ is larger than a value. * Support joint coding if the payload size of LP HARQ-ACK ~~and/or HP HARQ-ACK~~ is smaller than a value. * FFS for other UCIs |
| Panasonic | We support the first proposal. On the consideration of the number of HP/LP HARQ-ACK bits, even when the total number of payload size is large, there is possibility that either the number of HP or LP HARQ-ACK bit is 1 or 2 bits. In such case joint coding may be more appropriate coding scheme.  We are fine with the second proposal. |
| Sony | We do not agree with both proposals. We share similar views with Nokia in that we have a unified solution, i.e. separate coding regardless of the number of bits. |
| InterDigital | Agree with updated proposal from Samsung.  The original proposal is a bit unclear with the “and/or”. Based on simulation results, it seems that separate coding is better than joint coding when the number of HP bits is small. Intuitively, this also makes sense since otherwise a lot of energy is wasted by bringing up the reliability of LP bits to unnecessary high level. For the opposite case (number of LP bits is small), the performance of joint and separate coding is likely not very different. |
| Intel | We are fine with second proposal.  **Regarding first proposal, option of supporting both separate and joint coding seems to be an optimization at the expense considerable increase in specification impact and would require lot of discussion, such as how to identify the threshold above (below) which separate coding (joint coding) applies.** In our view, among the options of solutions, joint coding seems to cause least specification impact and it can be made to work. Regarding the concern that joint coding for large LP HARQ-ACK payload could impact reliability of HP HARQ-ACK, several suggestions have been made by companies such as partial dropping of LP HARQ-ACK bits, compression or bundling etc. so that desired code rate can be maintained.  **To this end, we suggest to support joint coding for any payload > 2 bits and put an FFS details on payload control of LP HARQ-ACK bits when needed.** |
| Sharp | Agree in principle.  For proposal 1, the detailed payload threshold can be FFS.  For proposal 2, it is better to clarify which priority is assumed for “the same priority”. For example, the two bits are treated with the highest priority among the HARQ-ACK bits, i.e. priority index 1. |
| ITRI | We do not agree with the proposal 1. A single coding scheme (i.e., joint coding) is preferred. As pointed by QC, OPPO and Intel, HARQ-ACK compression/bundling/dropping can be applied for LP HARQ-ACK to ensure the reliability of HP-HARQ-ACK.  We are fine with the second proposal. |
| CATT | We support the proposals. |
| vivo | For the first proposal, agree with updated proposal from Samsung. When joint coding is used, to guarantee the reliability of HP HARQ-ACK, small code rate of HP HARQ-ACK should be used, if the LP HARQ-ACK bits are to large, it will need too many PRBs.  For the second proposal, agree in principle. We prefer to treat the 2bits as HP. |
| Lenovo, Motorola Mobility | Not support the first proposal:  When the total number of LP and HP HARQ-ACK bits is more than 2 bits, we prefer joint encoding as long as the effective code rate is not higher than the configured max code rate (i.e. as long as the total payload size is less than a payload size determined by the max code rate and the max PRB).  If the effective code rate is higher than the configured max code rate, the UE shall not multiplex LP HARQ-ACK bits with HP HARQ-ACK bits in a PUCCH of a corresponding slot/sub-slot.  Support the second proposal. |
| Ericsson | In summary, we also have issue with first proposal since our preference is unified solution.  For second one, we are fine in principle, but reviewing the comments, it would be also fine to investigate if we can increase the reliability of PF0. However, we prefer methods with minimum impact on gNB. |
| LG | We are supportive with the first proposal in principle, but it needs to be more specific.  From our perspective, separate encoding is to be baseline except for the cases where one of LP UCI and HP UCI has relatively small UCI payload size (e.g. up to 2 bits) or the total payload of LP UCI and HP UCI has small size (e.g. up to 11 bits), in this case, joint encoding of LP/HP UCIs might be beneficial in terms of obtaining coding gain and potential CRC protection based on single encoding for the total payload of LP/HP UCIs. For all other cases, separate encoding would be beneficial in terms of efficient resource utilization and minimizing LP UCI dropping based on encoding with the maximum UCI coding rate configured per each of LP/HP UCIs.  In this context, our suggestion is as below.  Updated proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits,   * Support separate coding if the total payload size of LP HARQ-ACK and~~/or~~ HP HARQ-ACK is larger than a value X, and the payload size of both LP HARQ-ACK and HP HARQ-ACK is larger than a value Y. * Support joint coding if the total payload size of LP HARQ-ACK and~~/or~~ HP HARQ-ACK is equal to or smaller than a value X, or the payload size of either LP HARQ-ACK or HP HARQ-ACK is equal to or smaller than a value Y. * FFS for other UCIs   For the second proposal, we are also fine with it. |
| WILUS | For proposal 1, we still see the benefit of single and unified solution (separate coding), but we are ok to support both separate coding and joint coding as a compromised solution. Our view is that joint coding can be used when at least one of LP HARQ-ACK or HP HARQ-ACK is no more than 2 bits.  For proposal 2, we are fine with DCM’s modification. Regarding “FFS for other UCIs”, we think HP-SR can be multiplexed in PF0/PF1 as in R15/16, but other UCIs are not. So, we suggest to change “FFS for HP-SR” instead of “FFS for other UCIs”. |
| Spreadtrum | Agree with updated proposal from Samsung. If the bit number of LP HARQ-ACK is large, separate coding should be applied even if bit number of HP HARQ-ACK is small. |
| Huawei, HiSilicon | 1. **We don’t like the first proposal** though maybe we can compromise for progress   We prefer to adopt a single coding approach, i.e. separate coding for the case of more than 2 bits, where all the current coding scheme can be reused directly. With the first proposal here, we will need further evaluation/discussion on how to set the threshold.   1. **Support the second proposal in principle**.   For the case of 2 bits case, we think it is ok to do as the second proposal here, since it can be expected that the impact from the 1 bit LP HARQ-ACK on the HP HARQ-ACK is low, and the reliability for 1 bit HP HARQ-ACK would be not a problem in this case. |
| NEC | For proposal 1, our first preference is a single coding approach for multiplexing HARQ-ACK of different priorities on a PUCCH, i.e. joint coding. It is simple and does not need much specification work, the reliability of HP HARQ-ACK can be guaranteed by LP HARQ-ACK bundling/compression. Our second preference is the updated proposal from Samsung.  Support proposal 2. |
| ETRI | We think that the unified solution to the PUSCH and the PUCCH is desired, and support separate coding. |
| Xiaomi | Agree with the Proposal after 1st round discussion:  Between the two options for PF 0/1, we support Option 1 in both cases, since currently, no simulation results show the PUCCH reliability of PF 0/1should be enhanced for URLLC, so multiplexing resource reusing R15 PF 0/1 is already sufficient. Option 2 is somehow seems over optimization. |
| APT | For proposal 1, we prefer Option 2. Option 3 is also okay with the conditions determined based on simulation results.  For proposal 2, we share similar view as Qualcomm that HP HARQ-ACK should be protected. Option 2 provides higher reliability for HP HARQ-ACK than Option 1, and we don’t see any multiplexing issue regarding Option 2. |

## 2nd round proposal and discussion

Proposal:

For multiplexing a HP UCI and a LP UCI into a PUCCH in R17, select a coding scheme (e.g. joint coding, separate coding) targeting:

* The link performance of HP UCI is not worse than that in R15 due to multiplexing with LP UCI.

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| Company | Comments |
| QC | Thanks FL very much for the proposal.  Unfortunately, the proposal is not convincing to us. This WID is URLLC, for HP UCI, it has to meet high reliability requirement, which is at least 10^-4 (or even 10^-5) BER. Shooting for same performance as Rel-15 does not make sense. Also, we think it is physically impossible to keep HP UCI performance without degradation, after multiplexing it with LP UCI, given a same transmission power (or SNR) before and after multiplexing. With more bits transmitted after multiplexing, Eb/No for HP UCI has to drop and it will degrade performance.  In our view, there are two design principle for this open issue. One is shooting for “just make the system work, not targeting any performance optimization”. Following this, we just reuse Rel 15 multiplexing with joint encoding. There is neither spec impact nor UE implementation change. NW just rely on boosting UE Tx power to guarantee the performance of HP UCI. The system can work. But it has low coverage. To solve this issue, we can compress the size of LP to effectively boost the performance of HP, without boost Tx power too much.  The second principle is shooting for “performance optimization for HP UCI”. Following that direction, separate encoding for >2 bits was proposed. Following the same direction, new schemes for 1-bit HP+1-bit LP were proposed. We don’t see the logic to say that separate encoding is needed but new schemes for 1-bit HP+1-bit LP are not needed. If RAN1 are chasing after performance optimization, how could we leave the most important use case out?  Again, we see the comparison is very simple, “joint encoding with optional compression” vs “separate encoding with different coding rate”. Since the HP UCI performance will be the SNR bottle neck. Given the same HP UCI BER (say 10^-4 and 10^-5) and HP UCI undetectable error rate, the scheme achieves it with smaller SNR wins.  I suggest we agree on simulation scenarios/assumptions such as # HP bits, # LP bits, # OFDM symbols, etc, in this meeting. Then companies can run simulations and report required SNR to achieve HP target BER and target undetectable error rate. Decision can be made by comparing the reported SNRs with these two schemes. |
| Nokia, NSB | Do not agree  First of all, we would like to get clarification if this is related to the case of more than 2 bits or if this includes the case of 2 bits (according to our understand for up to 2 bits there is no real coding involved (but just selection of CS / modulation).  Assuming now >2bits: We appreciate the effort here, but as commented yesterday in the GTW session, it is not just about performance of the PUCCH assuming the number of HARQ-ACK bits / CB size is known, but will moreover need to consider that the reliability of the LP HARQ-ACK codebook size determination may not be on the same level of that of HP HARQ-ACK, which for joint coding of larger total payload sizes (>2bit) may lead to HP decoding errors. Therefore, if a comparison is done based on performance, the reliability of the LP HARQ-ACK CB size should be considering here as well. |
| Huawei, HiSilicon | We appreciate the effort and agree that simulation can be used to help select the coding scheme, but it should not be the only criteria, the selection should be based on analysis on other aspects also, e.g. resource efficiency, PUCCH multiplexing capacity, etc. |
| ZTE | Not clear about the intention of this proposal. If the intention of this proposal is to ensure that multiplexing does not affect the reliability of HP UCI, maybe the below proposal is more suitable, otherwise, we are confused about why performance of HP UCI should not worse than that in R15 since PHY priority is not supported in R15.  Proposal:  For multiplexing a HP UCI and a LP UCI into a PUCCH in R17, select a coding scheme (e.g. joint coding, separate coding) targeting:   * The link performance of HP UCI is not worse than that ~~in R15 due to multiplexing with LP UCI~~ before multiplexing. |
| OPPO | We share view with Huawei/HiSi that LLS performance is one of criteria but not only one.  We also share view with ZTE that LLS performance is compared between w/o multiplexing and w/ multiplexing.  So, we suggest update proposal:  For multiplexing a HP UCI and a LP UCI into a PUCCH in R17, select a coding scheme (e.g. joint coding, separate coding) targeting:   * At least, The link performance of HP UCI is not worse than that ~~in R15 due to multiplexing with LP UCI~~ before multiplexing. |
| LG | We share the same view with Huawei that PUCCH resource efficiency and multiplexing capacity need to be analyzed together with link performance. |
| Sony | We share same view with Nokia and Huawei. Also the performance should be better than R15 rather than not worse than as per QC’s comment. |
| Sharp | We share views with Nokia and Huawei on PUCCH resource efficiency besides LL performance.  We also agree with ZTE and OPPO on that the HP UCI performance is not worse than without multiplexing. |
| DOCOMO | We are not supportive of the proposal with the targeting “The link performance of HP UCI is not worse than that in R15 due to multiplexing with LP UCI.” It is possible that neither joint coding nor separate coding can satisfy the targeting after multiplexing. We propose to modify the targeting as “provide better/guaranteed HP UCI performance with less LP UCI performance degradation”. For example, SINR threshold for 1E-4/1E-5 BLER for HP UCI, and corresponding LP UCI BLER with the SINR threshold can be compared.  With regarding to simulation, we think we’d better compare performance with only coding scheme difference (i.e. separate and joint coding) and same assumptions for other simulation assumptions (e.g. resource for multiplexed UCI, etc.). Another concern from our perspective is about joint coding with LP UCI compression. As we understand, it will lead to LP UCI information loss which can’t be captured by BER/BLER performance. So we’re not sure whether it’s fair to compare “joint coding + LP UCI compression” with “separate coding without compression” with BLER/BER performance. |
| Panasonic | We share the same view with Huawei that in addition to link performance, other aspects such as resource efficiency should also be analyzed. |
| Apple | Qualcomm raised some good points there, they should be considered. For example on “HP UCI undetectable error rate”, with joint encoding with a sufficiently large payload size, CRC with polar coder can be used for error detection, but it may happen with separate encoding, CRC based error detection is not there anymore, and HP UCI also suffers from a lower SINR due to multiplexing with LP UCI; the case for separate encoding is not clear at this time. |
| TCL | We do not support the proposal, we share the same view with Huawei, link performance is not the only criteria to determine the coding scheme, other aspects should be considered. In addition, we also agree with ZTE, to guarantee the reliability of HP UCI, the link performance comparison should between the multiplexed UCI and the HP UCI before multiplexing. |
| vivo | We share the same understanding with Nokia that for up to 2 bits there is no real coding involved, but just selection of CS / modulation. We agree with HW and other companies that LL performance is not the only one criterial, other perspective, such as HARQ-ACK codebook reliability should also be considered. According to our understanding, the number of HP or LP UCI bits, channel coding scheme and the coding rate can impact on performance. For some combinations of UCI bits, channel coding scheme and coding rate, the joint coding with compression can outperform the separate coding. For other combinations, separate coding shows the better gain than joint coding. This is the reason we support both separate coding and joint coding under some condition. If simulation is required, the conditions should be aligned e.g. the number of HP or LP UCI bits, channel coding scheme and the coding rate. |
| QC2 | Hearing all the comments so far, we think what DCM suggested is a good way forward. We suggest to modify the proposal in that direction as following:  **Proposal: For multiplexing a HP UCI and a LP UCI into a PUCCH in R17, select a coding scheme (e.g. joint coding, separate coding) which achieves the following performance requirements for multiplexed HP and LP UCI with a smaller SNR**   * **Performance requirements for HP UCI**   + **10^-4 or 10^-5 bit error rate**   + **10^-2 false alarm rate**   + **10^-3 undetectable error rate (for >2 bits UCI)** * **Performance requirements for LP UCI**   + **10^-2 or 10^-3 BER**   + **10^-2 false alarm rate**   + **10^-2 undetectable error rate (for >2 bits UCI)**   **The selection should also take the following factor into consideration**   * **Specification impact** * **UE and gNB implementation complexity** * **Resource efficiency** * **PUCCH multiplexing capacity** * **Impact to DL PDSCH throughput with potential LP UCI compression**   **Note 1: false alarm rate is the probability that DTX is detected as a correct payload.**  **Note 2: undetectable error rate = # instances that a UCI payload is declared as correct when the UCI payload is in error / Total # instances that UCI payloads are in error, where a UCI payload is declared as correct if it passes the error detection check (with details up to each company, and to be reported)**  The definition of undetectable error rate is a copy-and-paste from the agreements (in RAN1 103e) for the study did in Rel-17 PUCCH coverage enhancement SI. |
| CATT | Thanks FL for the efforts. Similar as others, we do not think the LLS performance is the only criteria and other factors need to be taken into account. |
| Spreadtrum | Agree with QC’ update proposal. |
| ITRI | Share the same view with Huawei that link performance is not the only one criteria. And we also agree with ZTE and OPPO’s view that the HP UCI performance should not worse than without multiplexing. As for the LP UCI, compared with the Rel-16 dropping rule, whether to enhance performance or further optimize, other factors in addition to performance comparisons should be considered (e.g., specification effort, implementation complexity). |
| Samsung | We appreciate the effort for the proposal. We are not clear about the intention as well. We also share similar views as Nokia, the reliability of LP HARQ-ACK codebook needs to be taken into consideration for joint coding.  Even if we have to do simulation, it is better that we can have some common assumptions.  Compressing of LP HARQ-ACK should not be considered to compare joint coding and separate coding.  First, it will be difficult to compress Type-1 HARQ-ACK codebook because there are lots of padding NACKs there, simple bundling will result significant degradation of LP HARQ-ACK. A unified solution should be support as the baseline for both Type-1 and Type-2 HARQ-ACK codebooks, i.e., multiplexing.  Second, even for Type-2 HARQ-ACK codebook, there can be padding NACK, for example, when the numbers of CBG per PDSCH are different on different serving cells, the HARQ-ACK bits per PDSCH is determined based on the maximum number. It will be difficult to have a common solution for bundling/compressing and the standard impact can be large.  Third, for Type-2 HARQ-ACK codebook, if bundling is performed, gNB may falsely take a NACK as ACK if the last DCI is missing. This case should be avoided. |
| Intel | Few points:   * For any coding scheme, we need to compare performance of before and after multiplexing for HP UCI * As mentioned during GTW, compression is one candidate to be considered for joint coding, but not the only way. Partial dropping can be considered too. Also, joint coding with compression may lead to LP UCI information loss which may not be captured by BLER. Hence, agree with comments above from DoCoMo that joint coding with compression cannot be directly compared with separate coding without compression. For partial dropping, retransmission of the dropped bits can be considered. * Agree with comments above that LLS certainly helps, but other criteria such as spec impact, resource efficiency, PUCCH capacity matters as well. |
| Lenovo, Motorola Mobility | * For UCI size larger than 2 bits (i.e. for PUCCH formats 2/3/4), a desired performance for PUCCH carrying jointly coded UCI of mixed priorities can be guaranteed by gNB properly configuring parameters *maxCodeRate,* *nrofPRBs,* and *nrofSymbols* and by UE multiplexing (compressed/non-compressed) LP HARQ-ACK only when the total payload (including LP and HP UCI) is not larger than the max payload size determined based on the configured parameters *maxCodeRate,* *nrofPRBs,* and *nrofSymbols.* * For UCI size up to 2 bits with/without positive SR, we think the PUCCH performance equivalent to R15 is good enough. |
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## 3rd round proposal and discussion

Proposal:

For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH in R17, select a code-domain scheme (for total number of LP and HP HARQ-ACK bits >2 and =2 respectively) based on simulation results and analysis following the criteria:

* The link performance of HP and LP HARQ-ACK is guaranteed after multiplexing, i.e. the scheme which achieves the following performance requirements for multiplexed HP and LP UCI with a smaller SNR is desired.
  + Performance requirements for HP HARQ-ACK
    - 10^-4 or 10^-5 bit error rate
    - 10^-2 false alarm rate
    - 10^-3 undetectable error rate (for >2 bits HARQ-ACK)
  + Performance requirements for LP HARQ-ACK
    - 10^-2 or 10^-3 BER
    - 10^-2 false alarm rate
    - 10^-2 undetectable error rate (for >2 bits HARQ-ACK)
* Resource efficiency.
* PUCCH multiplexing capacity.
* Impact to DL PDSCH throughput if compression/bundling/Partial dropping for LP HARQ-ACK is considered.
* The reliability of the LP HARQ-ACK codebook size determination.
* Specification impacts.
* UE and gNB implementation complexity.

Note 1: false alarm rate is the probability that DTX is detected as a correct payload.

Note 2: undetectable error rate = # instances that a UCI payload is declared as correct when the UCI payload is in error / Total # instances that UCI payloads are in error, where a UCI payload is declared as correct if it passes the error detection check (with details up to each company, and to be reported).

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| Company | Comments |
| OPPO | We are fine with above criteria in principle. |
| Huawei, HiSilicon | In general we could be fine with the proposal.  However, we are not sure how much it can help for selecting the solutions, since it is expected that it would be hard for a certain solution to win for all the above aspects. For example, if one solution is good for one aspect but bad for another aspect, then how to judge which one is more critical? More effort might be needed for some of the aspects, e.g. the ones need system simulation, which may result in less number of companies showing the results, in this case is it possible people will argue the observation from the limited simulation results not as reliable as the ones with more sources? In a word, it can be expected that even with all simulation results and analysis as the proposal here, it still not easy to move forward for selecting the solutions. |
| Sony | We are fine with the proposal. |
| Nokia, NSB | We are fine with the intention of the proposal for the case where the total payload is > 2 bits.  But, similar to Huawei, we are not sure how this proposal would really help to decide which coding approach to adopt.  For the simulation results, there would be a need to at least agree on some basic performance evaluation assumptions/parameters. Otherwise, it would be difficult to reach any conclusion if different settings/assumptions are considered by different companies.  We don’t support the proposal for the case where the total payload is =2 bits, as it’s not clear what is the intention of the proposal for this case.  In our view, for this case, we should treat the two bits as two high-priority HARQ-ACK bits. Any optimization (such as Option 2 proposed earlier) that would be agreed for the multiplexing of 1 bit high-priority HARQ-ACK and 1 bit low-priority HARQ-ACK wouldn’t be considered for the case where the two bits are of high priority – as for this case the Rel-15 mapping is used as already agreed in Rel-16. If some companies think that there is any issue with the existing mapping rule, this implies what was agreed in Rel-16 for the same high-priority case was not good enough. Besides, the network could still decide/control whether to allow multiplexing or not between HP and LP HARQ-ACK for such cases. |
| TCL | We are fine with the proposal. |
| Sharp | We are fine with the proposal. |
| Samsung | The simulation assumptions are unnecessarily complex and increase the likelihood of discrepancies and difficulty of conclusions at the next meeting.  Checking DTX-to-ACK (false alarm) is is meaningful for 1-2 HARQ bits and PDCCH BLER of 1% but, with multiple LP HARQ-ACK bits and 2 HP HARQ-ACK bits with PDCCH BLER in the order of 10-4 or less (e.g. at least an order of magnitude smaller than the target PDSCH BLER), that added level for potential discrepancies is not needed. The same applies with the undetectable error rate which is reasonable to consider for UEs with very low SINRs but that won’t be the case for UEs operating URLLC and transmitting many HARQ-ACK bits.  Therefore, simulation assumptions can and should be simplified only for the BLER as this would also remove potential discrepancies and allow for clean and direct comparisons.  The remaining aspects are already known. There is large throughout loss from compression based on results/conclusions from LTE – if needed, SLS can be re-run but hopefully we can rely on existing evaluations. The reliability of the LP HARQ-ACK is perfect for Type-1 and is as good as the gNB wants to make it for Type-2 by targeting a smaller BLER for the last DCI – but that affects both JC and SC and is something that the gNB can be assumed to consider when configuring multiplexing. The specification impact and gNB/UE complexity are expected to be same (e.g. Rel-16 supports both SC and JC). Resource efficiency will be better with SC and so will PUCCH multiplexing capacity. Also, we don’t need to optimize for corner cases of low payload – Rel-16 can apply.  Besides, we have a concern regarding the first sub- bullet, if the payload of LP HARQ-ACK is large, using joint coding may exceed the maximum number of PRB, in this case how to guarantee the link performance? If we assume the maximum number of PRB cannot be exceeded, it is not fair for separate coding.  Regarding the 4th sub-bullet, we are not clear about how to evaluate the impact to DL PDSCH throughput if compression/bundling/Partial dropping for LP HARQ-ACK is considered. For example, how it works for Type-1 HARQ-ACK codebook? |
| Intel | Agree with Huawei’s and Nokia’s points made above  We also think companies should not be mandated to provided simulations, it can only be encouraged. As Huawei mentioned several factors need to be taken into account and it is relative to companies to justify which factor(s) should be given greater considerations.  It is not clear how “code-domain scheme” applies for payload = 2 bits, since there is no encoding as such for PF0 and PF1 in Rel-15 design. Hence, we suggest to limit this to > 2 bits case.  Agree with Samsung that simulation assumptions can be further simplified. We are not sure whether undetectable error need to be modelled or whether this is part of RAN4 demod requirements. So we suggest to put it in bracket for now.  Regarding the case when total payload is 2 bits, we suggest to take Rel-15 design as baseline and assume both bits are HP. Moreover, gNB can always enable/disable multiplexing when needed. Optimization for this case is not strongly motivated.  We suggest following updates:  Proposal:  For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH in R17, select a code-domain scheme (for total number of LP and HP HARQ-ACK bits >2) based on one or more of the following the criteria:   * The link performance of HP and LP HARQ-ACK after multiplexing compared to performance before multiplexing, taking following performance requirements   + Performance requirements for HP HARQ-ACK     - 10^-4 or 10^-5 bit error rate     - 10^-2 false alarm rate     - [10^-3 undetectable error rate (for >2 bits HARQ-ACK)]   + Performance requirements for LP HARQ-ACK     - 10^-2 or 10^-3 BER     - 10^-2 false alarm rate     - [10^-2 undetectable error rate (for >2 bits HARQ-ACK)] * Resource efficiency. * PUCCH multiplexing capacity. * Impact to DL PDSCH throughput if compression/bundling/Partial dropping for LP HARQ-ACK is considered. * The reliability of the LP HARQ-ACK codebook size determination. * Specification impacts. * UE and gNB implementation complexity.   Note 1: false alarm rate is the probability that DTX is detected as a correct payload.  Note 2: undetectable error rate = # instances that a UCI payload is declared as correct when the UCI payload is in error / Total # instances that UCI payloads are in error, where a UCI payload is declared as correct if it passes the error detection check (with details up to each company, and to be reported). |
| QC | We support this proposal. With this proposal, after the study, at least RAN1 will have a clear view on the whole picture of this multi-dimensional problem. How to draw a conclusion based on all information available from the study is next step. At least, it avoids us to draw wrong conclusion without even checking the performance.  A few minor comments to the proposal. 1) maybe checking link level simulation is enough. We don’t see the need to do system simulation here for joint vs separate coding. 2) an editorial change: “10^-2 or 10^-3 BER” for LP could be updated to “10^-2 or 10^-3 bit error rate”, to be consistent with the wording used for HP.  To Nokia/Intel: We don’t see the rationale to treat =2 bits and >2 bits separately. Likely we mentioned before, RAN1 should apply a CONSISTENT design principle for these two cases. If we don’t optimize performance for UCI multiplexing Rel-17, we should treat them as same priority and just reuse Rel-15 UCI multiplexing for both cases and be done with them. If we optimize Rel-17 UCI mux, then we should consider optimization for both cases. Optimizing only >2 bits but not =2 bits does not make sense to us.  To us, we are OK to take either design principles, i.e., either optimize or not optimization UCI mux with different priorities. But we cannot accept treatment these two cases separately with different design principles.  To Intel: Undetectable error rate is a must to check. Like we explained in previous email discussion, given HP <11 bits and LP <11 bits, separate encoding may not work because it does not have CRC to check the detected message is correct or not. While with joint encoding, putting the two payloads together, we know that 11 bits CRC can offer 2^-11 error protection. Without seeing simulation results to demonstrate separate encoding can achieve the same undetectable error performance, we cannot accept separate coding, because it might not work. Please also notice that checking undetectable error is a common practice in past RAN1 study. It was checked in Rel-15 coding study and in Rel-17 PUCCH coverage enhancement study.  Regarding the proposal to check the performance before and after multiplexing, we don’t see the need to do it. If a UE can guarantee both HP and LP UCI after multiplexing can meet URLLC requirements, why does the UE care the performance delta before and after multiplexing?  To Samsung: The compression did in LTE study may not include compression scheme considering the asymmetric probability between ACK and NACK, which can minimize the impact to DL PDSCH throughput. Even without advanced compression, UE can just apply a simple dropping or bundling if the LP UCI payload size exceeding an upper bound, which can at least deliver half of the LP HARQ-ACK back to NW. The other half can be retransmitted by gNB trigger a type 3 codebook. Therefore, compression/partial dropping/bundling is a factor need to be included in this study. |
| DOCOMO | We are fine with the proposal in general but not clear why it includes =2 bits case as the original intention of the discussion is only for > 2 bits case. In the previous meeting, we agree to use PF0 and PF1 when the total number of LP and HP HARQ-ACK bits is 2 bits. There is no encoding as such for PF0 and PF1 in Rel-15 design as Intel commented above. Therefore, we suggest to limit this to > 2 bits case. |
| Spreadtrum | We are fine with the proposal for total payload >2 bits, but have concern on the necessarily of total payload =2 bits, and we agree with Nokia that some detailed and basic performance evaluation parameters should be determined to ease the comparison. For example, the HP bit HARQ-ACK number and LP HARQ-ACK bit number should be predetermined for each simulation case to get the required SNR. |
| ZTE | We are fine with above criteria for total payload >2 bits in principle, but we are still unclear about the criterion of PUCCH multiplexing capacity that whether this criterion is refer to the multi-user multiplexing capability of the PUCCH or the capacity to multiplex HP UCI and LP UCI on the PUCCH. @FL, @Qualcomm, would you clarify the understanding on PUCCH multiplexing capacity? We guess it may refer to the latter, but if so, does it mean that the multiplexed UCI will be transmitted in the PUCCH for original UCI to be multiplexed, not the new PUCCH resources?  Besides, we think the purpose of the LLS is to help for selecting the coding scheme, i.e., joint coding or separate coding. Compression/bundling/Partial dropping is not required for current simulation since this issue is too early to be decided before the determination of the coding scheme and possible compression/bundling/Partial dropping scheme candidates if joint coding is approved later.  In addition, we also agree Huawei, Nokia and Intel’s point above. We are not sure whether we need to discuss simulation assumptions. If most companies think it is necessary to discuss to push forward in next meeting, we are happy to. |
| vivo | As above mentioned, the number of HP or LP UCI bits, channel coding scheme and the coding rate can impact on performance.  Before performing simulation, basic evaluation assumptions/parameters should be aligned. Otherwise, the simulation results may be diverse due to different assumptions and it would be difficult to reach any conclusion.  In our understanding, undetectable error occurs in RM coding (without CRC) and Polar coding with the less CRC length, which relates the number of coding bits. Thus, some parameters should be clarified firstly, e.g., the number of HP HARQ-ACK bits and LP HARQ-ACK bits, code rate, number of PRBs, channel mode, etc.  We also suggest focusing on some typical cases (combination of parameters) to reduce the evaluation effort. |
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## Multiplexing enable/disable mechanism

## Inputs from Tdocs

* Option 1: DCI indication
  + ZTE (DCI or RRC), E///, vivo, Intel, Nokia, IDC, Sony, APT, ETRI, Samsung
  + Not support: MTK
* Option 2: RRC configuration
  + ZTE (DCI or RRC), OPPO, HW, CATT, vivo, Spreadtrum, IDC (for SPS), LGE, CMCC, ETRI (if no indication in DCI), Samsung, Apple, QC, Sharp, DCM

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|  | | Arguments | Counter arguments |
| Advantages | Flexibility | Even if the multiplexing timelines are met, the latency and reliability of high priority transmission should not be affected.  Straightforward method to select from Rel-16 and Rel-17 behaviors  URLLC traffic usually has a sporadic or periodic pattern, overlapping cases occur either occasionally or predictably.  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. |  |
| Problems of DCI-based indication | Not a unified solution | Not applicable in some cases, e.g. the case of HARQ-ACK for PDSCH(s) scheduling by fallback DCI or SPS HARQ-ACKs.  HW[4]: Not applicable for the case of multiplexing LP HARQ-ACK and HP SR also, since it is impossible for gNB to predict the state of SR. |  |
| extra DCI overhead |  |  |
| UE complexity | [MTK] 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. |  |

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 4:*** *The multiplexing indicator exists in the scheduling DCI or RRC parameter for the high priority transmission.* |
| OPPO | ***Proposal 2: Rel-17 multiplexing of UCIs with different priority is configured by RRC. And Only high priority UCI transmission is allowed even if Rel-17 multiplexing of UCIs with different priority is configured, when***   * ***Low-priority UCI is compressed to 0 bit;*** * ***Beta-offset in UL grant is set to 0.*** |
| Huawei | ***Proposal 3: Adopt RRC configuration to enable/disable the multiplexing of high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK on PUCCH, and the multiplexing of HARQ-ACK on PUSCH with different priorities.***   * ***If the RRC parameter indicates ‘Enable’, some extra conditions should be defined to check whether the latency/reliability of HP HARQ-ACK can be guaranteed for a certain overlapping case.*** |
| E/// | Proposal 4 In case of overlapping between PUCCH and/or PUSCH resources in a slot with different priorities, dynamically enabling or disabling UCI multiplexing on PUCCH or PUSCH is supported. |
| CATT | ***Proposal 8: Semi-static RRC configuration to enable/disable the multiplexing between channels with different priorities is supported.*** |
| vivo | ***Proposal 12: Semi-static indication and dynamic indication of intra-UE multiplexing and prioritization manner can be supported in Rel-17.***  ***Proposal 13: For dynamic indication, multiplexing or prioritization indicator filed can be included in DCI with HP or LP or both HP and LP.***  ***Proposal 14: For dynamic indication, a new field separately from priority indication can be included in DCI to indicate HP or LP channel to carry the multiplexed UCI.*** |
| MTK | Proposal 2: Dynamic indication of the multiplexing activation/de-activation is not supported. |
| Intel | **Proposal 5: DCI triggering HARQ-ACK may include an indication for enabling or disabling multiplexing.**   * **The indication may be applicable to both HARQ-ACK/HARQ-ACK and HARQ-ACK/SR multiplexing.** |
| Nokia | **Proposal 3.4: The gNB dynamically indicates, via an explicit field in the DCI scheduling high-priority HARQ-ACK, whether multiplexing of** **high-priority HARQ-ACK and low-priority HARQ-ACK (or more generally low-priority multiplexed UCIs) is enabled or disabled.** |
| Spreadtrum | 1. ***For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH, support RRC configuration to enable/disable the multiplexing as a baseline.*** |
| IDC | ***Proposal 2: DCI indicating HP HARQ-ACK also indicates if UE multiplexes HP HARQ-ACK with LP HARQ-ACK.***  ***Proposal 3: RRC configuration of SPS with HP HARQ-ACK includes an indication of whether the UE can multiplex HP HARQ-ACK with LP HARQ-ACK.***  ***Proposal 4: RRC configuration of a HP SR resource includes an indication of whether the UE can multiplex HP SR with LP HARQ-ACK.*** |
| Sony | **Proposal 4: The gNB dynamically enables/disable multiplexing in a HP PUCCH by an indication in the DL Grant scheduling the HP PUCCH.** |
| LGE | **Proposal #5: Prefer RRC configuration for the mechanism to enable/disable the multiplexing of HP HARQ-ACK and LP HARQ-ACK on PUCCH or the multiplexing of HARQ-ACK on PUSCH with different priority, with consideration of potential UE complexity and UCI/PUSCH reliability.** |
| TCL | **Proposal 2: If the total UCI bits exceed the payload of the multiplexed PUCCH resource, partially dropped low priority UCI and/or compressed/bundled low-priority HARQ-ACK should be supported.** |
| APT | Proposal 3 Dynamic indication is supported for indicating whether to multiplex overlapping high priority PUCCH and low priority PUCCH. |
| Lenovo/Moto | **Proposal 1:** A PUCCH resource and a corresponding priority index for multiplexing UCI of mixed priorities are determined based on the highest priority of the multiplexed UCI, in order to guarantee necessary reliability and low latency transmission. |
| CMCC | **Proposal 11: For multiplexing HP HARQ-ACK and LP HARQ-ACK into one PUCCH in R17, RRC signaling is used for gNB to enable/disable the multiplexing.**  **Proposal 12: Multiplexing of HP HARQ-ACK and LP HARQ-ACK is allowed only if RRC enabled and the defined multiplexing conditions are satisfied.** |
| ETRI | **Proposal 1: The scheduling DL-DCI has an additional field whether or not to allow multiplex HP UCI and LP UCI, or otherwise by the RRC signalling.** |
| Samsung | **Proposal 1: Support multiplexing UCI of different priorities subject to timeline conditions and RRC configuration and/or dynamic indication from gNB.**  **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.** |
| Apple | **Proposal 2: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, RRC configuration is used to enable/disable the multiplexing.** |
| QC | ***Proposal 16:* The Rel-17 intra-UE multiplexing feature is enabled/disabled via RRC configuration on per UE basis.**  ***Proposal 17:* 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.** |
| Sharp | **Proposal 4: RRC configuration is used as the mechanism to enable/disable the multiplexing of HP HARQ-ACK and a LP HARQ-ACK into a PUCCH.** |
| DCM | **Proposal 5:**   * *RRC configuration should be baseline for enabling/disabling multiplexing of LP and HP PUCCH* |

## 1st round proposal and discussion

Proposal for 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, the multiplexing can be enabled by RRC configuration.

* FFS other mechanisms, e.g. DCI indication
* FFS: Interaction between the enable/disable mechanism and other multiplexing conditions
* FFS for other types of UCI.

Support: DCM, QC, OPPO, Samsung, Pana, Sharp, ITRI, Apple, CATT, Lenovo/Moto, E/// (although desire an agreement on DCI also), LG, WILUS, Spreadtrum, TCL, HW/HiSi, NEC

Not support (should also agree on DCI indication now): Nokia/NSB, IDC, Intel

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| Company | Comments |
| DOCOMO | We are fine with the proposal. |
| QC | Support FL proposal.  RRC configuration has to be the baseline. Otherwise, it does not work for fall back DCI, SPS.  Please notice similar discussion happened on semi-static beta offset indication, which is agreed as baseline because UCI mux needs to work for fallback DCI, SPS, CG PUSCH etc. |
| Nokia/NSB | Do not support the proposal  In a similar way to any new features that get introduced in RAN1 specs, it would be first required to configure the UE with the above operation via RRC. So, we don’t really see anything special that would be needed in that regard.  In our view, it’s important to allow the network to *dynamically* control and avoid any potential impact of multiplexing on the high-priority HARQ-ACK from latency or reliability perspective. With such dynamic control, the network can instruct the UE, via the DCI scheduling the high-priority HARQ-ACK, to not multiplex the high- and low-priority HARQ-ACKs. For instance, if multiplexing would result in selecting a PUCCH resource that is a number of symbols later than the PUCCH resource that would contain high-priority HARQ-ACK only, the latency could be impacted as the high-priority HARQ-ACK transmission will be delayed a number of symbols. The network may find such a delay unacceptable and could thus disable the multiplexing operation.  Moreover, supporting dynamic indication for multiplexing through DCI signalling would ease the operation and specification effort also in other aspects:   * There may be no need to specify bundling / compression of low-priority HARQ-ACK information as the enabling/disabling of multiplexing could be dynamically indicated. * The handling of multiplexing of sub-slot PUCCH and slot-based PUCCH would be under direct gNB control. |
| OPPO | We support proposal in principle  The first FFS is not required. Condition for multiplexing can ensure reliability and latency requirement for URLLC. So, the benefit from DCI indication is not clear. But DCI overhead increase is significant. |
| ZTE | We support the multiplexing can be enabled/disabled by RRC configuration or DCI indication in different cases.  When the high priority HARQ-ACK corresponding to the SPS PDSCH or SPS PDSCH release, the multiplexing can be enabled/disabled by RRC configuration. For other cases, the multiplexing can be enabled/disabled by DCI indication as more scheduling flexibility at gNB side can be provided by DCI indication. |
| Samsung | Support |
| Panasonic | We are fine with the proposal. |
| Sony | We are fine with the proposal assuming that the RRC configuration includes configuring DCI to indicate whether to multiplex or not. |
| InterDigital | Do no support.  Agree with Nokia’s points that explicit control by DCI is required for dynamic scheduling. In addition, implicit rules may be insufficient because the 2-level priority indication does not capture all QoS requirements of the related traffic, which are only known at the gNB (for DL). |
| Intel | Do not support the proposal. Mostly agree with Nokia’s view above. DCI scheduling HP HARQ-ACK can include an indication to dynamically enable/disable multiplexing depending on overlap scenario. |
| Sharp | Support |
| ITRI | Support |
| Apple | RRC configuration should be the solution, support the FL proposal |
| CATT | We support the intention of the proposal. We think a single RRC configuration can be used to enable/disable UCI of different priorities in PUCCH. |
| Lenovo, Motorola Mobility | Fine with the proposal. |
| Ericsson | Support the proposal, but we agree with Nokia that it should be given that it is enabled/disabled by RRC. And what it important to enabled it dynamically as well. So, the progress would be that to have RRC configuration as baseline and support dynamic enable/disable on top. |
| LG | We are supportive the proposal, and RRC configuration is to be baseline.  For other approaches, it seems to need more discussions on potential aspects/behavior such as misalignment between UE and gNB. |
| WILUS | Support |
| Spreadtrum | We are fine with proposal |
| TCL | We support the proposal. |
| Huawei, HiSilicon | We are fine with the proposal in principle. We don’t think the first sub-bullet (i.e. FFS other mechanisms, e.g. DCI indication) is needed though, since relying on RRC configuration should be sufficient and mentioned in our paper DCI indication is not applicable to all cases. |
| NEC | Support the proposal. |
| ETRI | We think the DCI indication is necessary because good PUCCH resource may not be available due to some channel conditions. In our understanding, the gNB need a choice whether or not to multiplex LP UCI dynamically.  We support the proposal if the RRC configuration includes DCI approach, as Sony mentioned. |
| Xiaomi | Agree with the proposal. |
| APT | We share similar view as Nokia, DCI indication should be supported. Furthermore, if other conditions other than RRC configuration such as coding rates and timeline condition are used to determine whether to multiplex HP HARQ-ACK and LP HARQ-ACK, discrepancy of the conditions between gNB and UE may exist, which affects the multiplexing decisions of gNB and UE. As such, we think it is better to agree on DCI indication early so that details of DCI indication can be further studied. |

## PUCCH resource determination and mapping for multiplexing between HARQ-ACKs with different priorities

## Inputs from Tdocs

**PUCCH resource determination:**

* Option 1: Determine the PUCCH resource set 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
    - ZTE, OPPO, E///, MTK, Intel, NEC, Nokia, Spreadtrum, IDC, Sony, Pana, CMCC (if dedicated PUCCH resource for multiplexing is not configured), Sharp, DCM, Lenovo/Motorola Mobility
  + Other sub-options:
    - LGE (e.g. using configured priority)
    - Xiaomi (PUCCH resource from the PUCCH resource sets with lower maximum coding rate)
    - 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
  + HW, CMCC, ETRI

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| Resource determination for multiplexing between HARQ-ACKs with different priorities | | | |
|  | | Arguments | Counter arguments |
| Option 1a | Advantages |  |  |
| Option 2 | Advantages | [HW[4]]: Provide an extra benefit over Option 1a for easy verification whether the UE has missed the LP HARQ-ACK, otherwise there would be performance degradation. |  |
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**Resource mapping rules:**

* + If no enough resource for both HP and LP HARQ-ACK.
    - Option 1: LP HARQ-ACK is compressed/bundled/Compaction.
      * MTK, OPPO, NEC, Nokia, LGE (bundling for LP HARQ-ACK in spatial domain and/or CBG domain), TCL, Apple, WILUS
    - Option 2: LP HARQ-ACK is dropped.
      * Intel, LGE,
    - Option 3: LP HARQ-ACK is partially dropped.
      * Intel (partitioning in high and low priority), Nokia, TCL,
    - Option 4: Try multiplexing in the next slot/sub-slot as long as the originally scheduled PUCCH transmission spans across the next slot/sub-slot.
      * Lenovo/Moto

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 5:*** *When a PUCCH carrying high priority HARQ-ACK codebook overlaps with a PUCCH carrying low priority HARQ-ACK codebook, the following procedures are supported.*   * *The PUCCH resource set is determined based on the overall payload of the two HARQ-ACK codebooks.* * *The PUCCH resource used for transmission is determined by PUCCH resource indicator field in the last DCI that schedules the PDSCH corresponding to the high priority HARQ-ACK.* |
| OPPO | ***Proposal 3: A PUCCH resource for multiplexing of HP HARQ-ACK/SR and LP HARQ-ACK/SR should be selected from the PUCCH resources configured for HP HARQ-ACK/SR based on the total UCI.***   * ***No additional multiplexing timeline is needed.***   ***Proposal 4: When the total number of HP HARQ-ACK/SR and LP HARQ-ACK/SR exceeds the capacity of the multiplexing PUCCH,***   * ***If CBG-based transmission is configured, HARQ-ACK bundling across multiple CBGs of one TB is firstly used for LP HARQ-ACK;*** * ***For TB-based HARQ-ACK, HARQ-ACK bundling across multiple PDSCHs on one serving cell can be used for LP HARQ-ACK.*** |
| Huawei | ***Proposal 4: Support a dedicated PUCCH configuration to carry the multiplexed HP HARQ-ACK and LP HARQ-ACK.*** |
| E/// | Proposal 6 When PUCCH with HP HARQ-ACK/SR overlaps with PUCCH with LP HARQ-ACK:   * + 1. 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.   Proposal 2 In case of overlapping between PUCCH and/or PUSCH resources in a slot with different priorities, methods based on partial puncturing with or without resuming and HARQ-ACK bundling as part of overlapping resolution procedures are not supported. |
| MTK | 1. High priority PUCCH resources should be used for the multiplexing.   ***Proposal 5:*** Group-bundling is supported when multiplexing and when the resulted UCI payload is large. |
| Intel | **Proposal 3: Support joint coding of LP and HP HARQ-ACK payload bits when combined payload is more than 2 bits.**   * **Multiplexed HARQ-ACK payloads are transmitted using PUCCH configuration of HP codebook** * **LP HARQ-ACK payload bits can be partitioned or a threshold on the payload can be considered to maintain target code rate.**    + **Dropped portion of LP HARQ-ACK payload bits can be retransmitted.** |
| NEC | ***Proposal 2:*** *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 multiplexing eMBB and URLLC HARQ-ACK feedback on the URLLC PUCCH resource to ensure URLCC latency requirement.*  ***Proposal 4****: Support transmitting 1-bit indicator with multiplexed HARQ-ACK feedback as proposed in proposal 1 to explicitly indicate which codebook is bundled.* |
| Nokia | **Proposal 3.1: For the scenario where a PUCCH carrying high-priority HARQ-ACK overlaps with another PUCCH carrying low-priority HARQ-ACK: If the high-priority HARQ-ACK has a corresponding PDCCH, the multiplexing (if feasible) of high-priority HARQ-ACK and low-priority HARQ-ACK is done on a high-priority PUCCH resource.**  **Proposal 3.2: For the scenario where a PUCCH carrying high-priority HARQ-ACK overlaps with another PUCCH carrying low-priority HARQ-ACK: If the high-priority HARQ-ACK does not have a corresponding PDCCH, the multiplexing is not supported.**  ***Observation 3.1: Errors in low-priority HARQ-ACK codebook size determination may cause selection of different PUCCH resource set or use of smaller number of RBs for the multiplexed high-priority and low-priority HARQ-ACKs feedback than what gNB would expect. This problem of discrepancy on the determination of PUCCH resource and number of RBs is present regardless of whether joint or separate coding is used for the multiplexing of high-priority and low-priority HARQ-ACKs.***  **Proposal 3.3: RAN1 to define 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.**  ***Observation 3.3: Bundling only works for Type-2 HARQ-ACK codebook, since in case of Type-1 HARQ-ACK codebook most of the HARQ-ACK bits are typically representing a NACK. In addition, for low-priority Type-2 HARQ-ACK codebook with relatively large size, bundling/compression to only a couple of bits wouldn’t bring much benefits.***  **Proposal 3.7: On whether/how to bundle low-priority HARQ-ACK codebook bits when multiplexed with high-priority HARQ-ACK bits, RAN1 to down-select the following options:**   * **Option 1: bundling of low-priority Type-2 HARQ-ACK bits.** * **Option 2: partial dropping of low-priority Type-2 HARQ-ACK bits.** |
| Spreadtrum | 1. ***For multiplexing UCIs of different priorities in a PUCCH, PUCCH resources configured for HP should be chosen with first priority for piggyback to satisfy the URLLC requirement.*** |
| IDC | ***Proposal 5: DCI indicating HP HARQ-ACK also indicates the PUCCH resource for multiplexing HP HARQ-ACK and LP HARQ-ACK.***  ***Proposal 6: The PUCCH resource for multiplexing HP HARQ-ACK and LP HARQ-ACK is from the PUCCH configuration for HP HARQ-ACK.*** |
| Sony | **Proposal 3: When PUCCHs of L1 different priorities collide, the multiplexed UCI bits from these PUCCHs are carried by the High L1 priority PUCCH.** |
| LGE | **Proposal #8: Decide the configuration/determination of PUCCH resource used to multiplex/transmit UCIs with different priority.**  **Proposal #9: Consider how to generate the HARQ-ACK payload per each of LP and HP for the multiplexing of LP/HP HARQ-ACK on PUCCH (or PUSCH), according to HARQ-ACK codebook type (e.g. Type-1/2/3 codebook).**  **Proposal #6: Consider the bundling for LP HARQ-ACK in spatial domain and/or CBG domain for the case of exceeding the maximum UCI coding rate on PUCCH.**  **Proposal #7: Consider the partial dropping for LP HARQ-ACK according to HARQ-ACK codebook type for the case of exceeding the maximum UCI coding rate on PUCCH.** |
| TCL | **Proposal 2: If the total UCI bits exceed the payload of the multiplexed PUCCH resource, partially dropped low priority UCI and/or compressed/bundled low-priority HARQ-ACK should be supported.** |
| APT | **Proposal 2 Consider the following alternatives for PUCCH resource set determination when multiplexing high priority PUCCH and low priority PUCCH.**  **- Alt. 1: Use payload size of high priority UCI to determine PUCCH resource set.**  **- Alt. 2: An indication of which PUCCH resource set is selected is included in scheduling DCI.**  **- Alt. 3: Use payload size of high priority UCI and a configured payload size to determine PUCCH resource set.** |
| Lenovo/Moto | **Proposal 4:** If LP HARQ-ACK not multiplexed due to payload size limitation, UE can further check possible multiplexing in the next sub-slot, as long as a PUCCH of low priority index for LP HARQ-ACK is not confined to a current sub-slot. |
| Pana | **Proposal 2: For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH, PUCCH resource determination for multiplexing is based on PUCCH resource configuration for HP HARQ-ACK.**  **Proposal 3: For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH, PUCCH resource set is selected based on the total payload size.** |
| CMCC | **Proposal 5: For PUCCH resource determination used for multiplexing, the following alternatives can be further studied:**   * + If dedicated PUCCH resource for multiplexing is not configured, either HP PUCCH resource or LP PUCCH resource is used, depending on the priority indicator in the last DCI format;   + If dedicated PUCCH resource for multiplexing is configured, dedicated PUCCH resource is used. |
| ETRI | **Proposal 4: Whenever being transmitted, all the LP HARQ-ACK bits are multiplexed.**  **Proposal 6: Introduce additional PUCCH resource set for multiplexing HP UCI and LP UCI.**  **Proposal 7: Determine which DCI (between LP DCI and HP DCI) determines the final PUCCH resource.** |
| Xiaomi | ***Proposal 4: To guarantee the reliability of high priority channels, PUCCH resource from the PUCCH resource sets with lower maximum coding rate should be selected to convey the multiplexed information.*** |
| Samsung | **Proposal 7: The time unit for solving the collision of PUCCHs with different L1 priority indexes should be the HP PUCCH time unit.**   * **If a LP HARQ-ACK PUCCH overlaps with multiple HP PUCCH time units, determine an associated HP PUCCH time unit for the LP HARQ-ACK PUCCH.**    + **FFS details.** |
| Apple | **Proposal 1: Consider LP HARQ codebook size compaction for eMBB HARQ multiplexing over a high priority channel.** |
| Sharp | **Proposal 1: Multiplexing UCIs of different priorities in a PUCCH is supported if a processing timeline is satisfied so that the LP PUCCH can be fully dropped by the HP PUCCH.**  **Proposal 2: A HP PUCCH resource should be used for HARQ-ACK multiplexing with different priorities.** |
| DCM | **Proposal 4:**   * *PUCCH resourcet for HP HARQ-ACK is used for multiplexing LP HARQ-ACK and HP HARQ-ACK.* |
| WILUS | * ***Proposal 2. To multiplex UCIs with two priorities, 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.*** * ***Proposal 4: The required # of RBs for low-priority HARQ-ACK information may exceed the limit of PUCCH formats, then bundle the low-priority HARQ-ACK information. Detail bundling rules should be discussed in Rel-17 URLLC/IIoT WI.*** |

## 1st round proposal and discussion

Proposal for 1st round discussion:

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

* First determine a PUCCH resource set associated to HP HARQ-ACK based on the total number of HP HARQ-ACK and LP HARQ-ACK.
* Then determine a PUCCH resource in the PUCCH resource set based on the last DCI corresponding to the HP HARQ-ACK.

Proposal after 1st round discussion:

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

* + Use a PUCCH resource in the second *PUCCH-Config*.
  + FFS details

Support: DCM, QC, Nokia, OPPO, ZTE, Samsung, Pana, Sony, IDC, Intel, Sharp, ITRI, Apple, CATT, vivo, Lenovo/Moto, E///, LG, WILUS, Spreadtrum, TCL, HW, NEC, HW, Xiaomi, APT

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| Company | Comments |
| DOCOMO | We are fine with the basic idea of the procedure. But we think the description of “based on the total number of HP HARQ-ACK and LP HARQ-ACK” is not very proper for the case with separate coding for LP and HP UCI. As analyzed above, one of the advantages of separate coding is resource efficiency. So we propose that LP and HP code rate should be considered when determining PUCCH resource for separate coding case, e.g. an “effective payload size” can be introduced. |
| QC | We are fine with the spirit of this proposal. But some details of the proposal need further discussion. For example, in the two bits case, in PF0, even reuse Rel-15, both the CS indices of HP and LP are used to transmit 2 bits. So we cannot say only use the HP PUCCH resource. Similarly, in PF1, we have a proposal to use both HP and LP CS and then do resource selection between them. So it seems more appropriate to restrict the proposal to >2 bits first.  Even for >2 bits, whether the # LP bits before or after compression should be used to determine the resource? I recall there are proposals to set a fixed reference size for LP UCI to remove the impact DCI miss detection. If so, the reference size could be used to determine the PUCCH resource for combined HP+LP UCI.  Again, we are OK with the spirit of the proposal. We just suggest to settle down joint coding vs separate coding first, before make a decision on this. |
| Nokia/NSB | Do not support the current formulation of the proposal.  In our view, we should first agree on using a high-priority PUCCH resource for the multiplexing of high-priority and low-priority HARQ-ACKs.  How the PUCCH resource set is exactly determined, i.e. whether to determine the resource set based on the total number of high-priority and low-priority HARQ-ACK bits or not, could be discussed separately. One important related issue is the possible discrepancy between the gNB and the UE on the number of low-priority HARQ-ACK bits due to missing last DCI(s). In fact, errors in low-priority HARQ-ACK codebook size determination may cause selection of different PUCCH resource set or use of smaller number of RBs for the multiplexed high-priority and low-priority HARQ-ACKs feedback than what gNB would expect. It should be noted that this problem of discrepancy on the determination of PUCCH resource and number of RBs is present regardless of whether joint or separate coding is used for the multiplexing of high-priority and low-priority HARQ-ACKs.  Based on the above observations, we suggest the following updates:  Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * ~~First determine a PUCCH resource set associated to HP HARQ-ACK based on the total number of HP HARQ-ACK and LP HARQ-ACK.~~ * If the high-priority HARQ-ACK has a corresponding PDCCH, ~~Then~~ determine a PUCCH resource ~~in the PUCCH resource set~~ based on the last DCI corresponding to the HP HARQ-ACK. |
| OPPO | We are fine with proposal |
| ZTE | Support the proposal. |
| Samsung | Support in principle.  The wording is a little misleading and we suggest the following update.  Updated Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * First determine a PUCCH resource set configured in the second PUCCH-Config ~~associated to HP HARQ-ACK~~ based on the total number of HP HARQ-ACK and LP HARQ-ACK information bits. * Then determine a PUCCH resource in the PUCCH resource set based on the last DCI corresponding to the HP HARQ-ACK. * FFS: HP HARQ-ACK without corresponding DCI. |
| Panasonic | We are fine with the proposal. |
| Sony | We are fine with the proposal |
| InterDigital | We are fine with the following aspects:   * Determine a PUCCH resource set from the second PUCCH-Config * Determine a PUCCH resource based on the last DCI corresponding to the HP HARQ-ACK   However, for “total number of HP HARQ-ACK and LP HARQ-ACK”, we are not sure if this works always if we use separate coding and there is big discrepancy between the numbers of HP and LP bits. This may require further progress on the coding aspect. I suggest to modify as follows (starting from Samsung updated proposal):  Updated Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * First determine a PUCCH resource set configured in the second PUCCH-Config ~~associated to HP HARQ-ACK~~ based on the ~~total~~ number of HP HARQ-ACK and the number of LP HARQ-ACK information bits. * Then determine a PUCCH resource in the PUCCH resource set based on the last DCI corresponding to the HP HARQ-ACK. * FFS: HP HARQ-ACK without corresponding DCI. |
| Intel | Agree with the intention of the proposal. However, it is important to agree first that PUCCH resource corresponding to HP HARQ-ACK codebook is used for transmission for multiplexed bits. |
| Sharp | Agree in principle on selecting from HP PUCCH resources.  However, for PUCCH resource determination, the “total number of HP HARQ-ACK and LP HARQ-ACK” is ambiguous. It works for joint coding, but may be inappropriate for separate coding, esp, when the maximum code rate are very different for different priorities. In this case, a scaling factor (<1) can be applied to the LP HARQ-ACK payload for PUCCH determeination.  A more general description could be based on the “~~total~~ number of HP HARQ-ACK and LP HARQ-ACK”, the detailed methods should be discussed together with determined coding methods. |
| ITRI | We are fine with the proposal |
| Apple | The design principle is fine. |
| CATT | We agree with the intention of the proposal and agree with QC that if a reference number of LP HARQ-ACK is introduced, it should be used to determine the PUCCH resource set.  In addition, we would like to clarify whether/how the proposal applies to HP HARQ-ACK for SPS PDSCH. |
| vivo | Agree in principle on selecting from HP PUCCH resources.  For the first sub-bullet, we are not sure the PUCCH resource set is determined based on the total number of original HP HARQ-ACK and original LP HARQ-ACK, if separate coding is used, the corresponding code rate of HP HARQ-ACK and LP HARQ-ACK may be also needed. If joint coding is used, the LP HARQ-ACK can be that after compression or bundling.  For the second sub-bullet, FFS is needed for the case that HP HARQ-ACK is for SPS PDSCH. |
| Lenovo, Motorola Mobility | Fine with the proposal. |
| Ericsson | We are fine with the proposal in principle.  We prefer Samsung update of the proposal. |
| LG | We are fine with the first sub-bullet, but not supportive with the second sub-bullet.  We don’t see the reason to restrict the DCI used for PUCCH resource determination only within those corresponding to the HP HARQ-ACK. Moreover, considering the case where the HP HARQ-ACK doesn’t have corresponding DCI, e.g. SPS HARQ-ACK, Rel-16 rule to use the last DCI among all of LP and HP would be the unified solution. In other words, we don’t need to have additional FFS points on this PUCCH determination issue.  In this context, we suggest the following way.  Updated proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * First determine a PUCCH resource set associated to HP HARQ-ACK based on the total number of HP HARQ-ACK and LP HARQ-ACK.   Then determine a PUCCH resource in the PUCCH resource set based on the last DCI as in Rel-16 ~~corresponding to the HP HARQ-ACK~~. |
| WILUS | We are fine with the proposal with the following clarification. In “total number of HP HARQ-ACK and LP HARQ-ACK”, the LP HARQ-ACK is after bundling/dropping/compaction (if supported). Is it right understanding? |
| Spreadtrum | We are fine with proposal |
| TCL | We are fine with proposal |
| Huawei, HiSilicon | Some clarifications are needed for this proposal:  1. Is the PUCCH resource set in the first sub-bullet can be used for HP HARQ-ACK only transmission? If the answer is yes, we don’t agree with it. As we mentioned before, DCI miss-detection will result in ambiguity in this case, which will have impact on the performance of HP HARQ-ACK.  2. As commented by some other companies, if separate coding is used for HP HARQ-ACK and LP HARQ-ACK, it might not be good to use the total number of HP HARQ-ACK and LP HARQ-ACK to determine the PUCCH resource.  Considering many companies want to use the resource configured in the second PUCCH-config, we can compromise to some extent and suggest to modify the proposal as below:  Updated Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * First determine a dedicate PUCCH resource set configured in the second PUCCH-Config ~~associated to HP HARQ-ACK~~ based on the ~~total~~ number of HP HARQ-ACK and LP HARQ-ACK information bits.   + The dedicate PUCCH resource set is only used for multiplexing of HP HARQ-ACK and LP HARQ-ACK * Then determine a PUCCH resource in the PUCCH resource set based on the last DCI corresponding to the HP HARQ-ACK. * FFS: HP HARQ-ACK without corresponding DCI. |
| NEC | Support in principle.  Support that HP PUCCH resource is used for multiplexed HARQ-ACK transmission. The PUCCH determination is related to the detailed multiplexing scheme, which can be discussed further. |
| ETRI | If separate coding is considered, then the HP UCI and LP UCI have different code rate and the total number may not be the right metric as long as HP PUCCH resource set is used. Also, if HP SPS HARQ-ACK can be multiplexed by LP DCI, then this PUCCH resource corresponds to the LP resource set.  We agree in principle with the Huawei’s revision. |
| Xiaomi | Support the Proposal after 1st round discussion.  But for the first sub-bullet, maybe clarification should be add,  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * + Use a PUCCH resource in the second *PUCCH-Config*(the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK).   + FFS details |
| APT | Support the FL proposal. |

## 2nd round proposal and discussion

Proposal:

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

* + Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) at least in case the total number of LP and HP HARQ-ACK bits is more than 2.
    - FFS in case the total number of LP and HP HARQ-ACK bits is 2.
    - FFS details

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| Company | Comments |
| Nokia, NSB | We support the proposal, but would have preferred to cover the 2bit case as well using the same approach. |
| Huawei, HiSilicon | The DCI miss detection issue is critical to be solved, if the PUCCH resource is the one that configured for HP HARQ-ACK only transmission, then it will result in ambiguity at gNB side on whether LP HARQ-ACK is transmitted together with HP HARQ-ACK or not, thus have impact on the performance of HP HARQ-ACK. Therefore we would prefer to clarify that the PUCCH resource is only configured only for multiplexing of HP HARQ-ACK and LP HARQ-ACK. For progress, we can compromise to add an FFS in the proposal to leave more time for companies to check.  Proposal:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * + Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) at least in case the total number of LP and HP HARQ-ACK bits is more than 2.     - FFS: The PUCCH resource is configured only for multiplexing of HP HARQ-ACK and LP HARQ-ACK     - FFS in case the total number of LP and HP HARQ-ACK bits is 2.     - FFS details |
| ZTE | Support |
| OPPO | Support |
| LG | We prefer the following update since we think there is no need to differentiate behavior according to total payload size.  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17,   * + Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) ~~at least in case the total number of LP and HP HARQ-ACK bits is more than 2~~.     - ~~FFS in case the total number of LP and HP HARQ-ACK bits is 2.~~     - FFS details |
| Sony | We support the proposal. It would be good to have a unified solution for total HARQ-ACK bits = 2. |
| Sharp | Support |
| DOCOMO | Support |
| Panasonic | We support the proposal. |
| vivo | Support the proposal. We also prefer to have a unified solution for total HARQ-ACK bits = 2. |
| QC | We support FL original proposal. LG’s modification is not acceptable to us.  For 2 bits case, we’d like to keep resource selection on the table, because of the gain ~3dB it shows in PF1. Please notice that, when we multiplex 1 bit HP with 1 bit LP, the performance of HP automatically drops by 3dB because the UE essentially has to split power equally to transmit the HP and LP. Before multiplexing, for HP bit, the power is P. After multiplexing, for the HP bit, the power reduced to P/2. Using resource selection can gain the 3dB performance loss back, which is critical. If we really care about making this feature useful, we should chase improved schemes than reuse Rel-15 baseline for the 2 bit UCI case.  We admit that our proposal needs use two CS after multiplexing. But please notice more resource utilization is needed for >2 bits as well, no matter joint/separate coding is applied. gNB will need to provision more RBs for multiplexed HP+LP UCI, because of the payload size increment. From this perspective, we don’t see our proposal is less resource efficient than other enhancement scheme we are considering for HP+LP mux. |
| CATT | We support the proposal and share the same view as Nokia, LG and Sony that the same solution should be applied for total HARQ-ACK bits of 2 bits. |
| Spreadtrum | Support, and share the same view as LG that a unified solution should be applied for total 2 HARQ-ACK bits. |
| ITRI | Support this proposal |
| WILUS | We support the proposal and we also share the same view with LG that an unified solution regardless of bit-size is preferred. |

## Agreed proposals

Agreements:

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

* Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) at least in case the total number of LP and HP HARQ-ACK bits is more than 2.
* FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.
* FFS in case the total number of LP and HP HARQ-ACK bits is 2.
* FFS details

## Timeline and latency requirements

## Inputs from Tdocs

**Latency requirements:**

* Option 1: 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.
  + Option 1a: X=0.
    - HW, TCL
  + Option 1b: X>0.
    - CATT, CMCC
* Option 3: Controlled by gNB by dynamic indication whether to multiplex LP with HP or not.
  + Nokia/NSB

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 3: A PUCCH resource for multiplexing of HP HARQ-ACK/SR and LP HARQ-ACK/SR should be selected from the PUCCH resources configured for HP HARQ-ACK/SR based on the total UCI.***   * ***No additional multiplexing timeline is needed.*** |
| Huawei | ***Proposal 5: For HP HARQ-ACK overlapping with LP HARQ-ACK, the multiplexing is allowed only when the PUCCH carrying the multiplexed UCI ends no later than the PUCCH carrying HP HARQ-ACK.*** |
| CATT | ***Proposal 1: Multiplexing timeline should always be satisfied for overlapping channels with different priorities when multiplexing between UCIs with different priorities is supported.***  ***Proposal 2: For multiplexing of channels with different priorities, the multiplexing timeline is defined with reference to the start of a channel which would be used for multiplexing.***  ***Proposal 3: If the ending symbol of PUCCH or PUSCH for multiplexed UCI transmission is X symbols after the ending symbol of PUCCH for the higher priority UCI, LP channel should be dropped. FFS the value of X.*** |
| vivo | ***Proposal 6:*** ***Rel-15 multiplexing timeline should be starting point.*** |
| MTK | 1. Guard gap timeline of the new multiplexed PUCCH is of the earliest PUCCH. |
| TCL | **Proposal 4: Reuse multiplexing timeline of Rel-15, at lease as a starting point.**  **Proposal 5: Multiplexing for UCIs with different priorities should only be allowed when the PUCCH carrying the multiplexed UCI ends no later than the PUCCH carrying high-priority UCI.** |
| CMCC | **Proposal 2: Multiplexing of LP HARQ-ACK and HP HARQ-ACK/HP SR is allowed only if the following conditions are met:**   * **The existing Rel-15 timeline;** * **Latency check, i.e. the last symbol of PUCCH resource carrying multiplexed LP UCI and HP UCI is not X symbol(s) later than the original PUCCH resource for HP UCI;** * **Reliability check, i.e. the code rate or the total REs of the HP UCI after multiplexing is not larger than the code rate or less than the total REs before multiplexing**   **Proposal 9: 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 multiplexing rule in Rel-15 can be the starting point.** |
| Xiaomi | ***Proposal 3: The R15 multiplexing timeline can be reused for PUCCH/PUSCH with different priorities.*** |
| QC | ***Proposal 15:* Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.** |
| ITRI | **Proposal 1:**  The UE can multiplex HP HARQ-ACK in a LP PUSCH only if the processing time of LP PUSCH is sufficient. Otherwise, the UE should not perform the multiplexing and the LP PUSCH should be dropped.  **Proposal 2:**  To ensure the acknowledgement response validity, a UE should perform the multiplexing procedure only if the latest symbol for multiplexing the HP HARQ-ACK is not later than the latest symbol of the PUCCH. Otherwise, the UE should not perform the multiplexing. |
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## 1st round proposal and discussion

Void.

## 2nd round proposal and discussion

Proposal:

Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.

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| Company | Comments |
| QC | Support this proposal |
| Nokia,NSB | Support this proposal |
| Huawei, HiSilicon | Fine with the proposal. |
| ZTE | Support |
| OPPO | Support |
| Sony | Support |
| Apple | Support |
| Sharp | Support |
| DOCOMO | Support |
| Panasonic | We are fine with the proposal. |
| TCL | Support |
| vivo | Support |
| CATT | The proposal is not clear to us. Is the intention to say that the multiplexing timeline requirements need to be satisfied for PUCCH/PUSCH multiplexing with different priorities as in Rel-15 or the intention is that multiplexing timeline requirements may not be satisfied for all the PUCCH/PUSCH with different priorities and only PUCCH/PUSCH with different priorities which satisfy the multiplexing timeline are multiplexed. We support the former. Our proposals for multiplexing timeline requirements are as follows.  ***Multiplexing timeline should always be satisfied for overlapping channels with different priorities when multiplexing between UCIs with different priorities is supported.***  ***For multiplexing of channels with different priorities, the multiplexing timeline is defined with reference to the start of a channel which would be used for multiplexing.*** |
| Spreadtrum | Support |
| ITRI | We support this proposal |
| WILUS | Support |

## Agreed proposals

Working assumption:

Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities

* FFS whether or not to specify a different behavior than Rel-15 when the timeline requirements are not met

## Multiplexing HARQ-ACK and SR with different priorities

## Inputs from Tdocs

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Observation 2:*** *Reusing Rel-15 rules for the multiplexing of high priority SR and low priority HARQ-ACK may cause low reliability for SR or even dropping of SR.*  ***Proposal 6:*** *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 Reuse Rel-15 rules.*  *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.* | |
| Huawei | ***Proposal 6: For HP SR overlapping with LP HARQ-ACK of 1~2 bits,***   * ***Reuse the existing method in case of SR of F0/F1 and HARQ-ACK of F0, and SR of F1 and HARQ-ACK of F1,*** * ***Drop LP HARQ-ACK and transmit SR on its own PUCCH resource in case of SR of F0 and HARQ-ACK of F1.***   ***Proposal 7: For HP SR overlapping with LP HARQ-ACK of more than 2 bits, HP SR and LP HARQ-ACK are separately coded and multiplexed on a PUCCH resource selected from a dedicated PUCCH resource set configured for the multiplexed HARQ-ACK and SR.***  ***Proposal 8: For HP SR overlapping with LP HARQ-ACK of more than 2 bits, multiplexing is allowed only when the PUCCH carrying the multiplexed*** |
| E/// | Proposal 5 When PUCCH with HP SR overlaps with PUCCH with LP HARQ-ACK:   * + 1. 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.     2. 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. |
| vivo | ***Proposal 7: When HP SR with PUCCH format 0 overlaps with LP HARQ-ACK with PUCCH format 1, Rel-16 prioritization is reused.*** |
| Intel | **Proposal 10: Adopt the following tables for collision handling behavior of SR and HARQ-ACK of different priorities.**  **Collision handling HP SR and LP 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 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 |   **Proposal 11: P/SP CSI is dropped if its resource overlaps with HP SR or HP HARQ-ACK.** |
| Nokia | **Proposal 3.8: For the scenario where a PUCCH carrying high-priority SR overlaps with a PUCCH carrying low-priority HARQ-ACK:**   * **If SR is with F0 and HARQ-ACK is with F0/F1: the SR and HARQ-ACK are multiplexed and transmitted on the SR resource.** * **If SR is with F1 and HARQ-ACK is with F0/F1: Transmit HARQ-ACK on the SR resource if SR is positive; and transmit HARQ-ACK on the HARQ-ACK resource when SR is negative.** * **If SR is with F0/F1 and HARQ-ACK is with F2/F3/F4: If SR is positive, transmit SR on the SR resource and drop HARQ-ACK; if SR is negative, transmit HARQ-ACK-only on the HARQ-ACK resource.** |
| LGE | **Proposal #10: 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 #11: 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.** |
| Pana | **Proposal 8:**   * **For multiplexing a LP HARQ-ACK and a HP SR into a PUCCH, following HARQ-ACK/SR PUCCH format combination should be supported.**   + **HP SR and LP HARQ-ACK in a resource using PUCCH format 0**   + **HP SR in a first resource using PUCCH format 1 and LP HARQ-ACK in a second resource using PUCCH format 1**   + **HP SR and LP HARQ-ACK in a resource using PUCCH format 2, 3, or 4**   **Proposal 9:**   * **For multiplexing a LP HARQ-ACK, a HP HARQ-ACK and HP SR into a PUCCH, following two procedures are studied.**   + **Option 1: UE first resolve the overlapping for PUCCH transmission of HP HARQ-ACK and HP SR. After resolving the overlapping, multiplexing of LP 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 HP HARQ-ACK > HP SR > LP HARQ-ACK.** |
| CMCC | **Proposal 10: 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 considered.** |
| Xiaomi | ***Proposal 1: Support multiplexing between different resources not confined within a sub-slot if the different PUCCH resources are of different priorities.***  ***Proposal 2: If a slot based low priority PUCCH overlaps with multiple subslot based high priority PUCCH resources, and each subslot based PUCCH resources are contained in separate subslots, only multiplex the slot based PUCCH and the first subslot PUCCH resource, but not to multiplex both the two subslot high priority PUCCH together.*** |
| Samsung | **Proposal 6: Adopt the following rules for multiplexing/prioritization of HP SR and LP HARQ-ACK on a same PUCCH.**  **Table 2: Rules for multiplexing/prioritization of HP SR and LP HARQ-ACK on a same PUCCH**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | LP HARQ-ACK  HP SR | PUCCH format 0 | PUCCH format 1 | PUCCH format 2 | PUCCH format 3/4 | | PUCCH format 0 | Reuse R15 | Drop LP HARQ-ACK | Use LP HARQ-ACK PUCCH. FFS reliability enhancements. | Alt 1: Use LP HARQ-ACK PUCCH if latency can be satisfied. FFS reliability enhancements.  Alt 2: Drop LP HARQ-ACK if at least one overlapping SR is positive. Transmit LP HARQ-ACK if all overlapping SRs are negative. | |
| QC | ***Observation 4*: Multiplexing HARQ-ACK and SR with different priorities shall take into account the following design principles:**   * **Reuse the Rel-15 rule to multiplex the HARQ-ACK and SR when appropriate** * **High priority channels should be better protected to guarantee its reliability and latency via i) putting the multiplexed payload on the high priority PUCCH resources if possible ii) use the power control parameters related to the high priority channel to transmit the multiplexed payload.**   ***Proposal 5*: In NR Rel-17, if a HARQ-ACK (with single priority) transmission on PUCCH format 0 or PUCCH format 1 collide with one SR, the UE performs the actions in Table 4 to resolve the collision.**   * **FFS: collision resolution for 1-bit HP HARQ-ACK and 1-bit LP HARQ-ACK overlapping with 1-bit HP or LP SR**   Table 4. 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 6*: 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.** |
| Sharp | **Proposal 5: Support all PUCCH format combinations for LP HARQ-ACK and HP SR**  **Proposal 6: For multiplexing of HP HARQ-ACK, LP HARQ-ACK and SR, the multiplexing order and SR bit generation methods should be further clarified.** |
| DCM | **Proposal 6:**   * *Agree the table for UE behavior on multiplexing eMBB HARQ-ACK and URLLC SR as a baseline. Further considerations are needed for down-selection.*  |  |  |  | | --- | --- | --- | |  | **URLLC SR PF0** | **URLLC SR PF1** | | **eMBB HARQ-ACK PF0** | * Same as Rel-15/16 multiplexing for same priority to multiplex eMBB HARQ-ACK bit(s) and URLLC SR bit, but transmitted on URLLC SR PF0 resource | * 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 PF1 resource, URLLC SR and eMBB HARQ-ACK multiplexed by 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** | * Opt 1: If latency and reliability condition satisfied for eMBB HARQ-ACK resource, URLLC SR is appended after eMBB HARQ-ACK and transmitted on eMBB HARQ-ACK resource. Otherwise, eMBB HARQ-ACK is dropped and URLLC SR is transmitted. * Opt 2: eMBB HARQ-ACK is dropped and URLLC SR is transmitted. | | |
| WILUS | * ***Proposal 6:***    + ***To multiplex with 1-bit LP-HARQ and 1 HP-SR in PF0, reuse Rel-15 multiplexing rules without modification.***   + ***To multiplex with 1-bit LP-HARQ in PF1 and 1 HP-SR in PF1, reuse Rel-15 multiplexing rules without modification.*** * ***Proposal 7:***    + ***To multiplex with 2-bit LP-HARQ and 1 HP-SR in PF0, reuse Rel-15 multiplexing rules with swapping HP-SR and LSB of LP-HARQ.***   + ***To multiplex with 2-bit LP-HARQ in PF1 and 1 HP-SR in PF1, reuse Rel-15 multiplexing rules without modification.*** * ***Proposal 8:***    + ***To multiplex with 1-bit LP-HARQ and 1-bit HP-HARQ in PF0, use the new CS mapping.***     - ***CS=0, 3, 6, 9 for (HP-HARQ, LP-HARQ)=(NACK, NACK), (NACK, ACK), (ACK, NACK), (ACK,ACK).***   + ***To multiplex with 1-bit LP-HARQ in PF1 and 1-bit HP-HARQ in PF1, reuse Rel-15 multiplexing rules without modification.*** * ***Proposal 9:***    + ***To multiplex with 1-bit LP-HARQ, 1-bit HP-HARQ, and 1 HP-SR in PF0, use the new CS mapping.***     - ***CS=0, 3, 6, 9 for (HP-HARQ, HP-SR) = (NACK, -), (NACK, +), (ACK, -), (ACK, +) if LP-HARQ is NACK, or***     - ***CS=1, 4, 7, 10 for (HP-HARQ, HP-SR) = (NACK, -), (NACK, +), (ACK, -), (ACK, +) if LP-HARQ is ACK.***   + ***To multiplex with 1-bit LP-HARQ in PF1, 1-bit HP-HARQ in PF1, and 1 HP-SR in PF1, reuse Rel-15 multiplexing rules without modification.*** |
|  |  |

## 1st round proposal and discussion

Void.

## 2nd round proposal and discussion

Here to collect companies’ views on necessity for R17 enhancements for HP SR+LP HARQ-ACK multiplexing. Companies are encouraged to input in the table. We will try to focus on some combination in the discussion.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | LP HARQ-ACK | | |
| PF0 | PF1 | PF2/3/4 |
| HP SR | PF1 | Case 1 | Case 3 | Case 5 |
| PF0 | Case 2 | Case 4 | Case 6 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Company | Necessity for R17 enhancements  (N=No R17 enhancement, Y=Need R17 enhancements) | | | | | |
| Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 |
| Example | N | N | Y | N | Y | Y |
| **Nokia, NSB** | **Y**  Transmit HARQ-ACK on the SR resource if SR is positive; and transmit the HARQ-ACK on HARQ-ACK resource when SR is negative. (different from Rel-15/Rel-16 rule for same priority case) | **Y**  Transmit both on the SR resource (Small change compared to Rel-15/Rel-16 rule for same priority case) | **N**  Follow the Rel-15 rule for same priority case, i.e. transmit HARQ-ACK on the SR resource if SR is positive; and transmit HARQ-ACK on the HARQ-ACK resource when SR is negative. | **Y**  Transmit both on the SR resource (different from Rel-15/Rel-16 rule for same priority case) | **N**  Follow the Rel-16 rule, i.e. if SR is positive, transmit SR on the SR resource and drop HARQ-ACK; if SR is negative, transmit HARQ-ACK-only on the HARQ-ACK resource. | **N**  Follow the Rel-16 rule, i.e. if SR is positive, transmit SR on the SR resource and drop HARQ-ACK; if SR is negative, transmit HARQ-ACK-only on the HARQ-ACK resource. |
| Huawei, HiSilicon | N | N | N | Y (drop LP HARQ-ACK instead) | Y | Y |
| ZTE | Y | Y | N | Y | Y | Y |
| LG | Y | Y | N | Y | N | N |
| Sony | Y | Y | Y | Y  Transmit +ve SR + HARQ-ACK in PF0 | N | N |
| Sharp | Y  HARQ-ACK on SR PUCCH for positive SR, on HARQ-ACK PUCCH for negative SR | Y  Transmit on HARQ-ACK PUCCH using a different CS for positive HP SR, e.g. CS+1 over positive LP SR | Y  HARQ-ACK on SR PUCCH for positive SR, on HARQ-ACK PUCCH for negative SR | Y  Transmit HP SR, drop HARQ-ACK. | Y  Prepend or append HP SR bits to LP HARQ-ACK | Y  Prepend or append HP SR bits to LP HARQ-ACK |
| DOCOMO | Y | Y | **N**  (Follow the Rel-15 rule for same priority case, i.e. transmit HARQ-ACK on the SR resource if SR is positive; and transmit HARQ-ACK on the HARQ-ACK resource when SR is negative.) | Y | Y (with latency and reliability condition) | Y (with latency and reliability condition) |
| Panasonic | Y | N | Y | Y | Y | Y |
| vivo | Y  Multiplexing as Rel-15 with the same priority | Y  Multiplexing as Rel-15 with the same priority | Y  Multiplexing as Rel-15 with the same priority | N  Transmit HP SR, drop HARQ-ACK as Rel-16 | Y  Multiplexing as Rel-15 with the same priority | Y  Multiplexing as Rel-15 with the same priority |
| QC | Y | Y | Y | Y | Y | Y |
| CATT | Y | Y | N | Y | N | N |
| ITRI | Y | Y | N | Y | N | N |
| Samsung | Before discussing these detailed cases, it is better that we could first agree on some basic issues.  LP HARQ-ACK can be multiplexed with HP SR and LP SR respectively.  So far, multiplexing of LP HARQ-ACK, HP SR and LP SR is not supported.  Our first question is whether this scenario is going to be supported? If not, should the LP SR and HP SR be differentiated when multiplexed with LP HARQ-ACK?  In the last meeting, it is agreed to support multiplexing between different resources not confined within a sub-slot. Considering the following figure.    Without multiplexing with LP HARQ-ACK, UE can transmit both SRs. Simply reuse Rel-15 rules, UE can only choose one SR from the two. There will be information loss for HP traffic.  Our second question is whether HP SR information loss is acceptable when multiplexed with LP HARQ-ACK? The issue applies to other PUCCH formats as well, if we discuss case by case there can be too many combinations.  Our suggestion is we can discuss the multiplexing order and rules first without considering PUSCH. This case has to be solved anyway. Then we can discuss the detail cases as suggested by FL.  As suggested in our contribution, for PUCCH multiplexing of different priorities. First, we need to define a time unit. The HP time unit (slot/sub-slot) is preferred. Second, LP HARQ-ACK can be linked to a HP time unit (slot/sub-slot), i.e., put the LP HARQ-ACK in the set Q of the HP slot/sub-slot. Third, Rel-15 rules can be applied.  The result PUCCH should be confined within the selected HP slot/sub-slot considering latency and spec impact, otherwise, prioritization should be performed. | | | | | |
| Intel | Y | Y | Y | N  Drop HARQ-ACK and transmit SR on SR resource | Y | N  except when HARQ-ACK is of PF2 |
| Lenovo, Motorola Mobility | Y | Y | Y | Y | Y | Y |
| As pointed by Samsung, different time units for PUCCH resources of different priorities and overlapping of multiple HP SR occasions with LP HARQ-ACK occasion should be considered. | | | | | |
| WILUS | Y | Y | N  (Rel-15 behavior, i.e., HARQ-ACK is transmitted on SR PUCCH resource if positive SR) | N  (Rel-16 behavior, i.e., transmit HP SR and drop LP HARQ) | N  (Rel-16 behavior, i.e., transmit HP SR and drop LP HARQ) | N  (Rel-16 behavior, i.e., transmit HP SR and drop LP HARQ) |
| No. of “N” | 1 | 2 | 8 | 3 | 6 | 7 |
|  |  |  |  |  |  |  |

## 3rd round proposal and discussion

Based on the 2nd round discussion, it is considered to first focus on the Case 1, 2, 4 in Section 2.6.3. The aim of following proposals is to list the candidate options, and trigger the cross-check between companies.

Proposal 2.6.4-1 (Case 2):

When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, further study the following options:

* + Opt.1: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource.
  + Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource. If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
  + Opt.3: 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.
  + Opt.4: The SR and HARQ-ACK are multiplexed and transmitted by using 4 CS values on the HARQ-ACK resource. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
  + Opt.5: No enhancement.

Proposal 2.6.4-2 (Case 4):

When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, further study the following options:

* + Opt.1: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource.
  + Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource. If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
  + Opt.3: For positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
  + Opt.4: 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.
  + Opt.5: Drop HARQ-ACK and transmit SR on its own PUCCH resource.
  + Opt.6: The SR and HARQ-ACK are multiplexed and transmitted by applying QPSK on the HARQ-ACK resource. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
  + Opt.7: No enhancement.

Proposal 2.6.4-3 (Case 1):

When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, further study the following options:

* + Opt.1: Transmit HARQ-ACK on the SR resource if SR is positive, and transmit HARQ-ACK on the HARQ-ACK resource when SR is negative.
  + Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource. If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
  + Opt.3: For positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
  + Opt.4: 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.
  + Opt.5: The SR and HARQ-ACK are multiplexed and transmitted by using 4 CS values on the HARQ-ACK resource. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
  + Opt.6: No enhancement.

Proposal 2.6.4-4:

Further study the different time units for PUCCH resources of different priorities and overlapping of multiple HP SR occasions with LP HARQ-ACK occasion

|  |  |
| --- | --- |
| Company | Comments |
| OPPO | In our understanding, the intention of discussion is to identify cases to be studied not to down select corresponding solutions. So, we suggest modify proposals:  Updated proposal 2.6.4-1:  For R17 enhancements for HP SR+LP HARQ-ACK multiplexing, further study the following combinations:   * A PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0 * A PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1 * A PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0   The intention of proposal 2.6.4-4 is not clear for us. In our understanding, the following agreement has covered proposal 2.6.4-4.   |  | | --- | | Agreements:  For multiplexing UCIs of different priorities in a PUCCH in R17,   * Support of multiplexing between different resources not confined within a sub-slot if conditions are met   + FFS: Details * Support multiplexing in case a PUCCH overlaps with more than one PUCCH if conditions are met   + FFS details |   If there are some special handling for overlapping between SR and HARQ-ACK, it’s better to identify in proposal. |
| Huawei, HiSilicon | We are fine with listing the options for each case for further study. Without fully understand the potential enhancements for each case, it is hard to make decision whether enhancements needed or not for a certain case.  However, we have some question for clarification as below:  **For Proposal 2.6.4-1 (Case 2)**:  1. Further clarification on how to transmit SR and HARQ-ACK on the SR resource are needed, e.g. reuse the Rel-15 rule on HARQ-ACK resource?  **For Proposal 2.6.4-2 (Case 4)**:  1. Further clarification on how to transmit SR and HARQ-ACK on the SR resource are needed?  2. We proposed to modify option 5 as below:   * + Opt.5: If SR is positive, drop HARQ-ACK and transmit SR on its own PUCCH resource. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.   **For Proposal 2.6.4-3 (Case 1)**:  1. Further clarification on how to transmit SR and HARQ-ACK on the SR resource are needed?  2. It seems option 1 and option 3 are the same. |
| LG | In principle, we are also fine with listing potential options with inclusion of Opt.4/6/5 for Proposal 2.6.4-1/2/3, respectively, as in the above.  In addition, we are OK with the above HW’s modification to Opt.5 in Proposal 2.6.4-2.  BTW, we also have one question for understanding on Proposal 2.6.4-2: Opt.3 and Opt.4 seems to be the same, isn’t it? |
| Sony | We are fine with Proposals 2.6.4-1 to 2.6.4-4. However, we need some clarifications:  **Proposal 2.6.4-1:**   * For Option 3, it isn’t clear which PUCCH resource the UE is supposed to use for a negative SR. If UE is to use the SR PUCCH resource, then it is no different to Option 1.   **Proposal 2.6.4-2:**   * It is unclear what’s the difference between Option 3 & Option 4. * For Option 4, for -ve SR, is the UE going to use the HARQ-ACK PUCCH resource ?   **Proposal 2.6.4-3:**   * It is unclear what’s the difference between Option 3 & Option 4. |
| Nokia, NSB | We are fine with the proposals. |
| Sharp | We are fine with the intention of the proposals in general. However, more calrification is needed on details.  **Proposal 2.6.4-1:**   * Option 1: the SR PUCCH resource with PF 0 is normally configured with only one cyclic shift (CS) value. For HP SR PUCCH resourc, multiple cyclic shifts need to be reserved with Option 1. * A different CS value can be applied on HARQ-ACK PUCCH to differentiate HP SR and LP SR as part of Option 3 or a new Option.   **Proposal 2.6.4-2:**   * Option 1 is unclear whether it is applied for positive SR only or for all cases. If it is only for positive SR, then it becomes the same as Option 3 & Option 4. Again, multiple CS values need to be reserved or configured for the HP SR PUCCH resource with PF0. * With Option 5, it is applicable only for positive HP SR. For negative SR, the LP HARQ-ACK is transmitted.   **Proposal 2.6.4-3:**   * Option 1 and Option 3 are essentially the same. It can be extended to all cases for HP SR PUCCH with PF1, i.e. LP HARQ-ACK with either PF 0 or PF1. |
| Samsung | As we clarified in the second round discussion. Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK need to be considered. For “No enhancement” we assume it includes both Rel-15 and Rel-16 behavior. We suggest the following update for the first three proposals.  “No enhancement”=>“No enhancement (including Rel-15 and Rel-16 behavior)”  Add the following FFS for each proposal.  FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?  Regarding proposal 2.6.4-4, thank you FL for the effort for proposal. We would like to clarify a bit more.  The time unit issue applies to LP HARQ-ACK multiplexing with HP HARQ-ACK and/or HP SR as well, we think a unified solution is preferred, therefore, we suggest the following proposal.  Update proposal 2.6.4-4:  Further study determination of the PUCCH time unit for handling the PUCCH collision case when different PUCCH time units of different priorities are configured. When A LP HARQ-ACK PUCCH overlaps with more than one HP sub-slot, at least following cases should be considered.   * Case 1) Each HP sub-slot contains zero or more HP SR PUCCH resource. * Case 2) Each HP sub-slot contains zero or more HP HARQ-ACK PUCCH resource. * Case 3) Each HP sub-slot contains zero or more HP SR PUCCH resource and zero or more HP HARQ-ACK PUCCH resource. * Note: Multiplexing of PUCCH with different priorities is performed within a PUCCH time unit.   Regarding the case when a LP HARQ-ACK PUCCH overlaps with multiple HP SR PUCCHs, it also need to consider the case when a LP HARQ-ACK PUCCH overlaps with multiple HP SR PUCCHs within the same PUCCH time unit. We suggest the following proposal.  Proposal 2.6.4-5:  Further study how to handle the cases when a LP HARQ-ACK PUCCH overlaps with multiple HP SR PUCCHs. At least PUCCH format 0 or 1 should be considered for LP HARQ-ACK PUCCH   * Case 1) All the HP SR PUCCHs are PUCCH format 0. * Case 2) All the HP SR PUCCHs are PUCCH format 1. * Case 3) Some HP SR PUCCHs are PUCCH format 0 and Some HP SR PUCCHs are PUCCH format 1.   From the previous discussion, some companies prefer to drop LP HARQ-ACK when overlapping with HP SR in some scenarios. If the LP HARQ-ACK also overlaps with a HP HARQ-ACK, how to address this issue should be clarified. For example, drop the LP HARQ-ACK or multiplex with HP HARQ-ACK. We suggest the following proposal.  Proposal 2.6.4-6:  When a LP HARQ-ACK overlaps with HP HARQ-ACK PUCCH and HP SR PUCCH simultaneously, further study how to handle the case if the LP HARQ-ACK can be multiplexed with HP HARQ-ACK but the LP HARQ-ACK cannot be multiplexed with HP SR. |
| Intel | More details are needed in Proposal 2.6.4-4. Is this targeting when one LP PUCCH overlaps with multiple HP PUCCHs in a slot, where HP PUCCH may be HARQ-ACK PUCCH as Samsung mentioned? Please clarify.  We are fine with listing the options for FFS in Proposals 2.6.4.1-3. Option 1 and 3 look similar in 2.6.4-3. |
| QC | We have a similar comment as OPPO. We thought the intension of the discussion is to prioritize different cases. We did not expect detailed proposals on how to do UCI multiplexing for each prioritized case. But we are fine to take one step further.  We have following comments for these proposals.  Comments to Proposal 2.6.4-1 (Case 2): Our proposal is not captured in the FL proposal. We’d like to modify “Opt.1: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource with a potential power boost to the multiplexed transmissions.” FL can capture either as a separate option 1a or modify option 1 directly.  Comment to Proposal 2.6.4-2 (Case 4): we are fine with the proposal and we support option 3.  Comment to Proposal 2.6.4-3 (Case 1): we are fine with the proposal and we support option 3.  A general comment: it seems many options are the same or at least very similar, which is essential resource selection. For example, option 2/3 in Proposal 2.6.4-1 (Case 2), option 2/3/4 in Proposal 2.6.4-2 (Case 4), option 1/2/3/4 in Proposal 2.6.4-3 (Case 1) all look same/similar to us. These options utilized resource selection to transmit SR+HARQ-ACK multiplexing. **In our proposal for 1-bit HP HARQ-ACK + 1-bit LP HARQ-ACK in PF1, we proposed a similar scheme to do resource selection. We just replace 1-bit SR by 1-bit HARQ-ACK. Nothing else is new.** **If we are open to study resource selection for SR+HARQ-ACK with different priorities, we suggest to study resource selection for HARQ-ACK+HARQ-ACK with different priorities too.** |
| DOCOMO | We are fine with the proposals in general but we also need some clarifications as follows:  **Proposal 2.6.4-1:**   * For Opt.1, share same question as HW/HiSi that it is not clear how to multiplex HARQ-ACK and SR on the SR resource. In our understanding, the cyclic-shift method as in Rel-15 behavior is used. However, in that case, the difference between Opt.1 and Opt.3 is not clear. Opt.1 and Opt.3 can be merged and Opt.3 seems one sub-option of Opt.1. * For Opt.2, it’s not clear whether SR information is included in the UCI bits, or implicitly indicated by PRB location? If the former understanding, it seems not clear how to include the SR information in the UCI bits. * For Opt.3, not sure why “PRB(s)” is indicated in this option. We don’t think it is needed in the description since frequency and also time domain resource change when selecting PUCCH resource. Propose to modify as “For positive SR, the UE transmits the PUCCH in the resource using PUCCH format 0 in ~~PRB(s) for~~ SR resource.” * For Opt.4, it seems better to use SR resource instead of HARQ-ACK resource. Therefore, we propose to change “on the HARQ-ACK resource” to “on the HARQ-ACK resource or the SR resource”, i.e. “The SR and HARQ-ACK are multiplexed and transmitted by using 4 CS values on the ~~HARQ-ACK~~ HP SR resource”   **Proposal 2.6.4-2:**   * For Opt.1, share same question as HW/HiSi that it is not clear how to multiplex HARQ-ACK and SR on the SR resource. In our understanding, the cyclic-shift method as in Rel-15 behavior is used. However, in that case, the difference between Opt.1/3/4 is not clear. Opt.1/3/4 can be merged. * For Opt.4, not sure why “PRB(s)” is indicated in this option. We don’t think it is needed in the description since frequency and also time domain resource change when selecting PUCCH resource. * For Opt.6, it seems better to use SR resource instead of HARQ-ACK resource. Therefore, we propose to change “on the HARQ-ACK resource” to “on the HARQ-ACK resource or the SR resource”, i.e. , “The SR and HARQ-ACK are multiplexed and transmitted ~~by applying QPSK on the HARQ-ACK resource~~ by using 4 CS values on the HP SR resource.”   **Proposal 2.6.4-3:**   * For Opt.3, this seems exactly same as Opt.1. If so, Opt.3 should be removed from the list. * For Opt.4, not sure why cyclic shift is used for multiplexing SR and HARQ-ACK in PF1. In our understanding, cyclic shift and TD-OCC are used for multiplexing different UEs in PF1. * For Opt.5, it seems better to use SR resource instead of HARQ-ACK resource. Therefore, we propose to change “on the HARQ-ACK resource” to “on the HARQ-ACK resource or the SR resource”, i.e. “The SR and HARQ-ACK are multiplexed and transmitted ~~by using 4 CS values on the HARQ-ACK resource~~ by applying QPSK on the HP SR resource.” |
| Spreadtrum | We are generally fine with the proposals, and Samsung’s added proposals can also be taken into consideration. |
| ZTE | We are fine with the proposals in principle, but we share the same view with OPPO about proposal 2.6.4-4. We are appreciated if some companies can clarify whether this proposal is for the case that there is an overlap between multiple HP SR and one LP HARQ-ACK, and the overlapped PUCCHs contain slot based PUCCH resources and sub-slot based resource (or SR confine in sub-slot).  For Proposal 2.6.4-1, we support Huawei that further clarification on how to transmit SR and HARQ-ACK. Besides, Opt.3 and Opt.4 can be merged into one proposal if needed.  For Proposal 2.6.4-2, Opt.1, Opt.3 and Opt.4 can be merged into one proposal, if needed, as new option 1:  Opt.1: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. The UE does not transmit negative SR.  @LG: Yes, you are right. Opt.3 in Proposal 2.6.4-2 is same as Opt.4. We suggest that Opt.1, Opt.3 and Opt.4 can be merged into one option as above.  @Sony: For Opt.3 in Proposal 2.6.4-1, the negative SR will be dropped and the HARQ-ACK will be transmitted. We think Opt.3 and Opt.1 can be merged into one option. For Opt.3 in Proposal 2.6.4-2, it is same as Opt.4, and we also think it can be further merged with Opt.1 and Opt. 4. For Proposal 2.6.4-3, the values of cyclic shift of sequence in Opt.3 and Opt.4 are different. It cannot be merged with Opt.4.  @DOCOMO:  In proposal 2.6.3-1/2, the PRB description in option3 and option4 doesn’t affect multiplexing of UCI, just describes the used frequency resource. For simplicity, words related to “PRB” could be deleted.  In proposal 2.6.4-3**:** For Opt.4, the value of cyclic shift mcs depends on HARQ-ACK information and b(0) depends on positive SR in PF1. For multiplexing different UEs in PF1, the traditional m0 could be used. |
| Apple | Our understanding is other options other than those enumerated are not excluded. We suggest to add a sub-bullet “other options not excluded” |
| vivo | For Proposal 2.6.4-1 (Case 2):  We prefer to reuse the multiplexing rule for PF0 SR and PF0 HARQ-ACK in Rel-15   * + Opt.X: If SR is positive, SR is multiplexed on the PUCCH of the HARQ-ACK PUCCH resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.   For Proposal 2.6.4-2 (Case 4):  We want to modify Opt.5 as following, which is prioritization in the same way as Rel-16.   * + Opt.5: If SR is positive, d~~D~~rop HARQ-ACK and transmit SR on its own PUCCH resource. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.   For Proposal 2.6.4-3 (Case 1):  We prefer to reuse the multiplexing rule for PF1 SR and PF0 HARQ-ACK in Rel-15  Opt. X: If SR is positive, SR is multiplexed on the PUCCH of the HARQ-ACK PUCCH resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource. |
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## Multiplexing scenarios, rules and order (incl. more than two overlapping channels)

## Inputs from Tdocs

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 9: For more than two overlapping channels, timeline and procedure for multiplexing and prioritization specified in 38.213 can be reused.*** |
| Huawei | ***Observation 1: For the multiplexing rule for the collision of more than 2 PUCCHs, the discussion should be delayed until the multiplexing rule for two colliding PUCCHs is agreed.*** |
| E/// | 1. In case of overlapping between PUCCH and/or PUSCH resources in a slot, the first step is to resolve overlapping between the PUCCH resources irrespective of the corresponding priority or slot/sub-slot association.   Proposal 8 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.  Proposal 9 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. |
| CATT | ***Proposal 5: For multiplexing of 1 bit HP HARQ-ACK, 1 bit LP HARQ-ACK and 1 bits HP SR, the following two options can be further considered:***   * ***Option 1: Multiplexing of 1 bit HP HARQ-ACK, 1 bit LP HARQ-ACK and 1 bit HP SR to a PUCCH resource with PF 2/3/4 for HP HARQ-ACK*** * ***Option 2: Multiplexing of 1 bit HP HARQ-ACK, 1 bit LP HARQ-ACK and 1 bit HP SR to a PUCCH resource with PF 0/1 for HP HARQ-ACK*** |
| vivo | ***Proposal 1: Support multiplexing a high-priority HARQ-ACK and a low-priority SR into a PUCCH in Rel-17.***  ***Proposal 2: The priorities of investigation scenarios bases on Table 1.***  *Observation 1: For UCI multiplexing with different priorities in Rel-17, transmission power should be further discussed*  ***Observation 2: If HP/LP UCI multiplexing is after resolving collision within the same priority, some UCIs may be dropped.***  ***Proposal 9: 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.*** |
| Intel | **Proposal 12: When a PUCCH overlaps with more than one PUCCHs in a slot, consider one step approach for joint multiplexing of UCIs of different priorities into a PUCCH resource if UE supports intra-UE multiplexing across different priorities, instead of two step Rel-16 prioritization.** |
| NEC | ***Proposal 5:***  *Support multiplexing of two Type-1 HARQ-ACK codebooks of different priorities on a PUCCH in Rel-17 as follows:*   * *Firstly, UE constructs the high-priority Type-1 HARQ-ACK codebook based on K1 set of high-priority HARQ-ACK as Rel-16, and constructs low-priority Type-1 HARQ-ACK codebook based on K1’ set obtained by removing values in the intersection of the two separate HARQ-ACK timing K1 sets of two Type-1 CBs from the K1 set of low-priority HARQ-ACK.* * *Then, UE pastes the two HARQ-ACK codebooks together as a multiplexed HARQ-ACK codebook.* |
| Nokia | ***Observation 3.2: In principle, multiplexing could be supported for all four possible combinations of high-priority HARQ-ACK overlapping with low-priority HARQ-ACK considering Type-1 and Type-2 codebooks. If there would be a need to prioritize some cases for the discussions, the cases involving same HARQ-ACK codebook type (Type-1/Type-2) could be discussed first. The case corresponding to multiplexing high-priority Type-1 HARQ-ACK and low-priority Type-2 HARQ-ACK could also be of interest.***  **Proposal 3.9: For handling the scenarios** **where a PUCCH of a given priority crosses the sub-slot boundary of the PUCCH config of another priority and overlaps with a PUCCH of another priority, adopt the following procedure:**   * **Multiplexing of low-priority PUCCH and high-priority PUCCH, 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.**   + **Additional conditions are FFS.**   **Proposal 3.10: For handling the scenarios with more than two overlapping PUCCHs of different priorities, adopt the following procedure:**   * **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.** |
| Spreadtrum | 1. ***In case a PUCCH overlaps with more than one PUCCH with different priorities, perform multiplexing/dropping of overlapping PUCCHs with the same priority first, and then deal with multiplexing/dropping of resulted PUCCHs with different priorities in general.*** |
| LGE | **Proposal #3: Consider additional condition for the processing of inter-priority multiplexing and the latency requirement for HP UCI.**  **Proposal #4: Discuss the overall multiplexing procedures/steps for the inter-priority multiplexing of UCIs on PUCCH/PUSCH.** |
| APT | Proposal 7 Dynamic indication is supported for indicating whether to multiplex overlapping high priority PUSCH and low priority PUCCH. FFS the indication method when semi-static beta offsets are configured. |
| Lenovo/Moto | **Proposal 1:** A PUCCH resource and a corresponding priority index for multiplexing UCI of mixed priorities are determined based on the highest priority of the multiplexed UCI, in order to guarantee necessary reliability and low latency transmission. |
| Pana | **Proposal 7: For multiplexing a high-priority HARQ-ACK and a low-priority HARQ-ACK into a PUCCH, after resolving the overlapping for PUCCH transmissions of same priority index, UE procedure for multiplexing HARQ-ACK codebooks with different priority indexes should be performed.** |
| CMCC | **Proposal 1: Support multiplexing a high priority SR in a low priority PUSCH conveying UL-SCH and/or low priority HARQ-ACK/CSI in R17.**  **Proposal 3: Support multiplexing in case a PUCCH overlaps with more than one PUCCH with principle of ensuring the performance of each HP PUCCH.**  **Proposal 4: The low priority PUCCH and the first high priority PUCCH satisfying the multiplexing conditions are multiplexed only if the PUCCH carrying multiplexed UCI(s) do not overlap with any other high priority PUCCH.**  **Proposal 14: Multiplexing in case a PUSCH/PUCCH overlaps with more than one PUCCH/PUSCH is supported with principle of ensuing the performance of each HP PUCCH/PUSCH.** |
| ETRI | **Proposal 2: Multiplex HP UCI, and check to multiplex each LP UCI at earliest order.**  **Proposal 3: Further study how to adjust the power of PUCCH for payload from the other priority.** |
| Samsung | **Observation 1: Multiplexing of LP HARQ-ACK codebook and HP HARQ-ACK codebook with same and/or different HARQ-ACK codebook types can be implicitly enabled by RRC via the configuration for HP/LP multiplexing.**  **Proposal 5: Consider solutions to ensure the reliability of multiplexing of LP Type-2 HARQ-ACK codebook and HP HARQ-ACK codebook and/or HP data.**  **Proposal 8: Down select from the following options for multiplexing/prioritizing LP HARQ-ACK PUCCH, HP HARQ-ACK PUCCH and HP SR PUCCH on a same PUCCH. FFS potential enhancements.**   * **Option 1) All PUCCHs are viewed with same priority – Rel-15 multiplexing applies.** * **Option 2) First, multiplex overlapping LP PUCCHs and overlapping HP PUCCHs, then multiplex resulting LP/HP PUCCHs (if there is overlapping)** * **Option 3) First, multiplex overlapping HP HARQ-ACK PUCCH and LP HARQ-ACK, then multiplex resulting PUCCH and SR PUCCH (if there is overlapping)**   **Proposal 9: Intra-UE multiplexing should be performed in the following order,**   * **Step1: Multiplexing PUCCH(s) and/or PUSCH(s) with the same priority index.** * **Step2: Multiplexing PUCCH(s) and/or PUSCH(s) with the different priority indexes.** |
| DCM | **Proposal 7:**   * *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.*   **Proposal 9:**   * *Discuss processing order of intra-UE multiplexing with different priorities and cancellation due to dynamic SFI/UL CI/semi-static TDD and SSB.* |
| WILUS | * ***Proposal 5: TDMed or FDMed mapping can be used to map UCIs with two priorities in a PUCCH.*** |
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# 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*

Agreements:

*For HARQ-ACK multiplexing on PUSCH of different priority in R17, support a mechanism for gNB to enable/disable the multiplexing.*

* *FFS the type of the mechanism, e.g. DCI indication and/or RRC configuration, beta\_offset=0*
* *FFS: Interaction between the enable/disable mechanism and other multiplexing conditions*
* *FFS for other types of UCI.*

## Coding for UCIs with different priorities (e.g. separate coding vs. joint coding)

## Inputs from Tdocs

* Option 1: Separate coding
  + HW, Intel, Nokia, APT, Lenovo/Moto
  + Arguments:
    - Match different reliability requirements to different maximal coding rate.
    - Separate beta-offsets are supported for different priority combinations.
* Option 2: Joint coding
  + QC

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 11: For multiplexing HP HARQ-ACK/CSI and LP HARQ-ACK/CSI on one PUSCH, support separate coding with different beta-offsets for these two UCIs.*** |
| vivo | ***Proposal 10: For encoding the UCIs with different priorities, it should be discussed whether and how to increase the number of separately encoded UCIs for PUSCH.*** |
| Intel | **Proposal 6: Separate encoding and beta-offset values are used for multiplexing LP and HP HARQ-ACK bits onto the PUSCH.**   * **LP HARQ-ACK payload bits can be partitioned or a threshold can be considered. Dropped LP HARQ-ACK bits can be retransmitted** * **Beta offset value less than 1, potentially including the value zero, is supported in Rel17.** |
| Nokia | **Proposal 3.16: For the scenario where multiplexing HARQ-ACK bits of different priorities in a PUSCH, RAN1 to adopt separate encoding for the HARQ-ACK bits of different priorities.** |
| APT | Proposal 4 Separate coding of high priority UCI and low priority UCI when multiplexed in a PUSCH is supported. |
| Lenovo/Moto | **Proposal 10:** UCI with different priorities that is multiplexed in PUSCH are separately encoded and rate-matched. |
| QC | ***Proposal 10:* For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits, compress the LP HARQ-ACK, joint encode the HP and LP HARQ-ACK, then multiplex them on PUSCH.**   * **FFS how to compress the LP HARQ-ACK prior to joint encoding.**   ***Proposal 11*: For multiplexing 1 bit high-priority (HP) HARQ-ACK and 1 bit low-priority (LP) HARQ-ACK into a PUSCH in R17, support joint coding of the HP and LP HARQ-ACK with unequal error protection.** |
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## 1st round proposal and discussion

Proposal for 1st round discussion:

For multiplexing HARQ-ACKs of different priorities in a PUSCH in R17,

* + Support separate coding for the HARQ-ACKs with different priorities.
    - FFS for conditions.
  + FFS for other UCIs, e.g. SR.

Support: DCM, Nokia, OPPO, ZTE, Samsung, Pana, Sony, Intel, Sharp, ITRI, CATT, vivo, Lenovo/Moto, E///, LG, WILUS, Spreadtrum, TCL, HW, NEC, ETRI, APT

Not support: QC

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| Company | Comments |
| DOCOMO | Support the proposal. |
| QC | Unfortunately, we cannot agree with the current proposal. Again, our concern on implementation side is that this is unified behavior between UCI mux on PUCCH vs UCI mux on PUSCH. We strongly prefer unified behavior to simplify UE implementation. Please notice that UCI multiplexing is already super complicated in Rel-15. Please see the ~10 pages Pseudo codes in 212.  More importantly, based on our study, performance of separate encoding is worse than joint encoding for both =2 bits and >2 bit UCI mux on PUSCH. Please see the performance in following two figures. We suggest proponents of separate encoding scheme study the performance via simulation then we can compare the results and make decision based on performance comparison.  Last but not least, I want to point out an issue of separate encoding, due to <=11 bits RM codes has no CRC, the FA rate of separate encoding is an issue. Suppose a UE transmits message A<=11 bits and B<=11 bits. With separate encoding, none of them has CRC. The messages could be decoded as two totally different message C and D. But without CRC, gNB can not detect this error. This undetectable error is a well known issue for RM code. For LP UCI, it might be OK. For HP UCI, this is not acceptable. With joint encoding, A+B>11 bits and Polar codes has CRC to protect from the undetectable error.  If we did not miss any contribution, we did not see any company check the undetectable error rate with separate encoding. With the undetectable error, separate encoding may not meet the requirement of URLLC. Before seeing study on undetectable error, we cannot agree with separate encoding.  **Fig 12: Performance comparison between separate encoding and joint encoding for 1 bit HP HARQ-ACK multiplexing with 1 bit LP HARQ-ACK on PUSCH**    **Fig 8: Performance comparison between separate encoding and joint encoding for 1 bit HP HARQ-ACK multiplexing with 8 bits LP HARQ-ACK on a PUSCH** |
| Nokia/NSB | Support the proposal.  We would like to clarify the content of “other UCIs” here (i.e. what is this FFS about). |
| OPPO | Support the proposal. |
| ZTE | Support the proposal |
| Samsung | Support |
| Panasonic | We are fine with the proposal. |
| Sony | Support the proposal |
| Intel | Support the proposal |
| Sharp | Support |
| ITRI | Support the proposal |
| CATT | We support the proposal. |
| vivo | Support the proposal. |
| Lenovo, Motorola Mobility | Support the proposal |
| Ericsson | We support the proposal. We are open to discuss wrt concerns raised. |
| LG | We are supportive with the proposal. |
| WILUS | Support |
| Spreadtrum | Support the proposal |
| TCL | We support the proposal. |
| Huawei, HiSilicon | Support the proposal. |
| NEC | Support the proposal. |
| ETRI | Support the proposal. |
| APT | Support the proposal. |
| Apple | After checking, we also don’t support this proposal |

## Enhancements for multiplexing parameters

## Beta-offset < 1

#### Inputs from Tdocs

Option 1: Support Beta-offset < 1

* + ZTE (>0), OPPO (incl.=0), Huawei (incl.=0), E/// (incl.=0), CAICT, CATT (incl.=0), MTK, Intel (incl.=0), Nokia (at least 0), Spreadtrum (0), Pana (at least 0), CMCC (incl.=0), ITRI (0), DCM

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 7:*** *In order to ensure the reliability of high priority transmission, some new beta\_offset values smaller than 1 and larger than 0 should be introduced.*  ***Proposal 8:*** *For the overlapping between high priority HARQ-ACK and low priority PUSCH, if the gNB allows a UE to multiplex the HARQ-ACK on PUSCH, the UE maps this HARQ-ACK to PUSCH resource elements no later than the last symbol of PUCCH resource for HARQ-ACK.* |
| OPPO | ***Proposal 2: Rel-17 multiplexing of UCIs with different priority is configured by RRC. And Only high priority UCI transmission is allowed even if Rel-17 multiplexing of UCIs with different priority is configured, when***   * ***Low-priority UCI is compressed to 0 bit;*** * ***Beta-offset in UL grant is set to 0.***   ***Proposal 7: To support multiplexing UCI in one PUSCH when the UE would transmit multiple overlapping PUCCH and PUSCH with different priority, the following mechanisms should be supported to ensure the latency and reliability of high-priority information:***   * ***The timeline of ending symbols used for UCI transmission should be considered.*** * ***Beta-offset values and*** ***scaling factors should be separately configured for different priorities.*** * ***Low-priority HARQ-ACK should be compressed when the actual coding rate is higher than a threshold.*** |
| Huawei | ***Proposal 9: For multiplexing LP HARQ-ACK on HP PUSCH, support beta-offset < 1 including beta-offset = 0.***  ***Proposal 11: For multiplexing HP HARQ-ACK/CSI and LP HARQ-ACK/CSI on one PUSCH, support separate coding with different beta-offsets for these two UCIs.*** |
| E/// | Proposal 11 For UCI multiplexing on PUSCH, a different target code rate and beta factor is considered for high priority HARQ-ACK.  Proposal 12 Additional value range of beta-offset less than 1 is supported.  Proposal 13 Support dynamically enable/disable multiplexing by beta factor (e.g. beta=0 to disable mux) |
| CAICT | ***Proposal 1: For the low priority of HARQ-ACK is multiplexed on a high priority PUSCH, the beta offset values need to be configured to be smaller than current beta offset values, even the values can be smaller than one.***  ***Proposal 2: For a UE supporting UCI multiplexing on PUSCH of different priorities:***   * ***Independent beta offsets for different priority cases*** * ***Independent scaling parameter can be configured for different priority cases*** |
| CATT | ***Proposal 10: For a UE supporting multiplexing between different priorities, consider enhancements to UCI multiplexed on PUSCH based on***   * ***Independent beta offsets for PUSCH with different priorities*** * ***Independently configured higher layer parameter scaling for PUSCH with different priorities*** |
| vivo | ***Proposal 11: For UCI multiplexing on PUSCH with different priorities, a beta-offset set to provide beta-offsets for LP UCI and HP UCI multiplexing on PUSCH should be indicated/configured by network.*** |
| MTK | 1. Two sets of beta-offset could be defined one for high priority UCI and one for low priority UCI multiplexing. 2. beta-offset < 1 could be supported to further protect the HP data when multiplexed with LP-UCI on PUSCH. |
| Intel | **Proposal 6: Separate encoding and beta-offset values are used for multiplexing LP and HP HARQ-ACK bits onto the PUSCH.**   * **LP HARQ-ACK payload bits can be partitioned or a threshold can be considered. Dropped LP HARQ-ACK bits can be retransmitted** * **Beta offset value less than 1, potentially including the value zero, is supported in Rel17.** |
| Nokia | **Proposal 3.11: For the scenarios of multiplexing HARQ-ACK bits in PUSCH of different priorities, RAN1 should specify:**   * **two additional sets of beta\_offset values:**   + **multiplexing low-priority HARQ-ACK in high-priority PUSCH;**   + **multiplexing high-priority HARQ-ACK in low-priority PUSCH;** * **new beta-offset value(s), at least 0, to allow gNB flexibly enabling/disabling multiplexing HARQ-ACK in PUSCH.** |
| IDC | ***Proposal 9: Support separate configuration of beta\_offset parameters for the following cases:***   * ***LP HARQ-ACK multiplexed in LP PUSCH*** * ***LP HARQ-ACK multiplexed in HP PUSCH*** * ***HP HARQ-ACK multiplexed in LP PUSCH*** * ***HP HARQ-ACK multiplexed in HP PUSCH***   ***Proposal 10: DCI format 0\_1 and 0\_2 can be configured with two beta\_offset indicator fields, where one is applicable to LP HARQ-ACK and the other to HP HARQ-ACK.*** |
| Sony | **Proposal 5: Four sets of ** offsets are configured for multiplexing of UCI into PUSCH of different L1 priorities.** |
| LGE | **Proposal #12: Support separate configuration of beta offset as well as alpha factor per each of UCI priority or per UCI priority combination (e.g. for LP and HP, or for LP only case and other cases), for each priority (e.g. LP, HP) of PUSCH.** |
| APT | Proposal 6 Separate beta offsets and scalings can be configured for low priority UCI multiplexed in low priority PUSCH, for low priority UCI multiplexed in high priority PUSCH, for high priority UCI multiplexed in low priority PUSCH and for high priority UCI multiplexed in high priority PUSCH. |
| Pana | **Proposal 10:**   * **For multiplexing a LP HARQ-ACK in a HP PUSCH (conveying UL-SCH only), enhancement of beta-offset values including , which allows for dropping LP HARQ-ACK should be supported.**   **Proposal 11:**   * **For multiplexing a HP HARQ-ACK in a LP PUSCH (conveying UL-SCH only), enhancement of beta-offset values including specific or non-numerical value, which allows for dropping LP PUSCH could be considered.** |
| CMCC | **Proposal 16: Introduce new beta offset values smaller than 1 to limit the total resources assigned to LP HARQ-ACK in R17.**  **Proposal 17: For multiplexing HARQ-ACK on PUSCH of different priorities, RRC signaling and/or beta-offset=0 can be used for gNB enable/disable the multiplexing.** |
| QC | ***Proposal 1:* Study modulation order and code rate selection for UCI multiplexed on PUSCH based on beta scaled spectrum efficiency of UCI.**  ***Proposal 7*: 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** |
| Sharp | **Proposal 7: For LP HARQ-ACK on HP PUSCH, re-use Rel-16 method with a separate beta offset.** |
| ITRI | **Proposal 3:**  For PUCCH multiplexed in PUSCH, beta\_offset configuration can be used to enable or disable the multiplexing. The multiplexing disabled if beta\_offset=0; otherwise the UE should perform the multiplexing. |
| DCM | **Proposal 8:**   * *For collision handling among PUCCH and PUSCH, UCIs are multiplexed on the PUSCH.*   + *In case the PUSCH is high priority, new beta-offset values should be introduced with separate configuration.* |

#### 1st round proposal and discussion

Proposal for 1st round discussion:

* Support beta-offset = 0.
  + FFS other values < 1.

Proposal after 1st round discussion:

* Support 0< beta-offset <1.
  + FFS values
  + FFS beta-offset =0.

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| Company | Comments |
| DOCOMO | Support the proposal. |
| QC | For now, we are not supportive on this proposal, but we are open to discuss. This essentially allows dynamically disable and enable UCI multiplexing on PUSCH. We don’t see this dynamic behavior very beneficial. Maybe proponents of this proposal can show the benefit of this proposal? Furthermore, this proposal cannot enable dynamic UCI multiplexing on PUCCH. It is a little strange that dynamic multiplexing is allowed on PUSCH but not on PUCCH. If dynamic multiplexing is beneficial, we prefer find a unified solution to enable it for both PUCCH and PUSCH. |
| Nokia/NSB | Support the main bullet.  On the FFS it should be ‘FFS other values <~~0~~1’, as negative beta seems not applicable |
| OPPO | Share view with Nokia/NSB |
| ZTE | Not support the proposal. We support beta-offset smaller than 1. Some companies propose that beta-offset can dynamically indicate whether low priority HARQ-ACK can multiplex on high priority PUSCH, i.e., beta-offset = 0 represents not supporting multiplexing. But the enable/disable of multiplexing based on beta-offset is inadequate, for example, if a high priority HARQ-ACK overlaps with a low priority PUSCH, and this HARQ-ACK cannot be multiplexed on the PUSCH due to the dissatisfaction of latency or reliability, how can the beta-offset indicate this case? It is more reasonable that the multiplexing can be indicated by other ways, like RRC parameter or DCI indication |
| Samsung | Not support.  Beta\_offset may not exist or may be 1 bit. Beta\_offset is an optional field.  Should not mix the functionality of beta\_offset and the functionality of a field indicating whether or not to multiplex. |
| Panasonic | We support the first bullet. On second bullet, we agree with Nokia. |
| Sony | Beta offset = 0 cannot be used to indicate not to multiplex for case where the UCI is HP and the PUSCH is Low Priority. Instead, we suggested that an entry in the Beta-offset table is reinterpreted as “No Multiplexing”. |
| InterDigital | Support in case the field in a HP DCI (for PUSCH) only. For HP UCI in LP PUSCH, it is useless (may as well not schedule LP PUSCH). The indication of whether to multiplex should be in the high-priority DCI. Another issue is that this should apply only to LP UCI in HP PUSCH, not HP UCI in HP PUSCH.  Suggested update:   * Support beta-offset = 0 in DCI for HP PUSCH to indicate that UE does not multiplex LP HARQ-ACK in HP PUSCH. |
| Intel | We can agree the following first if there is concern on support of beta-offset = 0.   * **Support 0 < beta-offset < 1**   + **FFS beta-offset = 0.** |
| Sharp | This can be discussed after enable/disable multiplexing signaling, i.e. RRC or DCI.  If supported, beta-offset=0 should only be applicable for LP HARQ-ACK on HP PUSCH. |
| ITRI | Share view with Nokia/NSB |
| CATT | Share view with Nokia/NSB |
| Lenovo, Motorola Mobility | Not support.  Multiplexing of HP UCI in LP PUSCH and multiplexing of LP UCI in HP PUSCH can be enabled/disabled via higher-layer configuration. |
| Ericsson | Share view with Nokia/NSB. |
| LG | We are open to introduction of such small beta offset values.  However, configuring those values is to be limited to the case of LP UCI (e.g. CSI) on HP PUSCH. |
| WILUS | No need to discuss support of beta\_offset = 0 separately. It is one option to enable/disable multiplexing so that discuss the issue in section 3.4 below first. |
| Spreadtrum | Share view with Nokia/NSB. |
| Huawei, HiSilicon | Fine with the proposal with modification as below：  Updated Proposal:   * Support beta-offset = 0.   + FFS other values < 1. |
| NEC | We share same view with Intel. |
| Xiaomi | Support the proposal. |

#### 2nd round proposal and discussion

Proposal for 2nd round discussion:

* For multiplexing LP HARQ-ACK in a HP PUSCH, support 0< beta-offset <1.
  + FFS values
  + FFS beta-offset =0.

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| Company | Comments |
| Nokia, NSB | Support the proposal |
| Huawei, HiSilicon | We are fine with the proposal. |
| ZTE | Support |
| OPPO | Support |
| Sony | It should be noted that beta-offset = 0 CANNOT be used for HP UCI multiplexing into LP PUSCH. Hence it will be good to consider a reinterpretation of beta-offset value to indicate NO Multiplexing, i.e. a modified proposal:   * For multiplexing LP HARQ-ACK in a HP PUSCH, support 0< beta-offset <1.   + FFS values   + FFS beta-offset =0 or beta-offset to indicate “No Multiplexing”. |
| Sharp | Support |
| Panasonic | We support the proposal. |
| vivo | Fine with the proposal. |
| QC | Before we agree on this proposal, we’d like to understand does this proposal impact beta\_offset indication in DCI. In other words, does it increase the number of bits beta\_offset? If Yes, we’d like to study this further to see if there are other ways to achieve the same goal of using <1 beta limit the impact of UCI mux on HP PUSCH. For example, can’t we introduce more aggressive alpha factor to protect HP PUSCH? At this stage, we want to keep it open and cannot agree on the proposal.  As for use beta-offset =0 to dynamically disable UCI mux, in general, we don’t see the need to introduce dynamic signaling for enable/disable UCI mux. |
| CATT | Fine with the proposal. |
| Spreadtrum | Fine with the proposal. |
| ITRI | Support this proposal |
| WILUS | Support |

#### Agreed proposals

Agreements:

For multiplexing LP HARQ-ACK in a HP PUSCH, support 0< beta-offset <1.

* FFS value(s)
* FFS to additionally support beta-offset =0 or a value disabling the multiplexing
* Aim to NOT increase the corresponding bitwidth in the DCI (compared to Rel-16)

## Separate configurations of alpha values?

#### Inputs from Tdocs

* Yes
  + CAICT, CATT, Sony, LGE, Lenovo/Moto, CMCC
  + 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///, Nokia
  + 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 | Proposals/observations from Tdocs |
| CAICT | ***Proposal 3: Support separate alpha values for different cases of UCI multiplexed on PUSCH.*** |
| Nokia | **Proposal 3.12: For the scenarios of multiplexing HARQ-ACK bits in a PUSCH of different priorities, do not support separate configurations of the scaling factor “alpha”.** |
| Sony | **Proposal 6: Separate ** offsets are configured for UCI of different L1 priorities for multiplexing into PUSCH.** |
| LGE | **Proposal #12: Support separate configuration of beta offset as well as alpha factor per each of UCI priority or per UCI priority combination (e.g. for LP and HP, or for LP only case and other cases), for each priority (e.g. LP, HP) of PUSCH.** |
| Lenovo/Moto | **Proposal 9:** Support configuring more than one scaling value for the variable , to allocate different maximum numbers of resource elements to UCI with different priorities. |
| CMCC | **Proposal 15: Support separate configuration of alpha for multiplexing with different priority combinations of HARQ-ACK and PUSCH.** |
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## Multiplexing enable/disable mechanism

## Inputs from Tdocs

Multiplexing enable/disable mechanism

* Option 1: By beta\_offset (e.g. beta=0 to disable mux)
  + OPPO, E///, CATT, Nokia, Spreadtrum, IDC, Sony, Pana, CMCC, ITRI
* Option 2: By new DCI field
  + vivo, Intel (for DG PUSCH), IDC, TCL, ETRI
* Option 3: By RRC configuration
  + OPPO, vivo, Intel (for CG PUSCH), IDC (for CG PUSCH and SPS), LGE, TCL, CMCC, ETRI (when no DCI indication), Apple, Sharp

The arguments are similar to that for Section 2.3.

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 2: Rel-17 multiplexing of UCIs with different priority is configured by RRC. And Only high priority UCI transmission is allowed even if Rel-17 multiplexing of UCIs with different priority is configured, when***   * ***Low-priority UCI is compressed to 0 bit;*** * ***Beta-offset in UL grant is set to 0.*** |
| Huawei | ***Proposal 3: Adopt RRC configuration to enable/disable the multiplexing of high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK on PUCCH, and the multiplexing of HARQ-ACK on PUSCH with different priorities.***   * ***If the RRC parameter indicates ‘Enable’, some extra conditions should be defined to check whether the latency/reliability of HP HARQ-ACK can be guaranteed for a certain overlapping case.*** |
| E/// | Proposal 4 In case of overlapping between PUCCH and/or PUSCH resources in a slot with different priorities, dynamically enabling or disabling UCI multiplexing on PUCCH or PUSCH is supported. |
| CATT | ***Proposal 9: A value of zero for beta-offset in a DCI can be used to dynamically indicate that LP UCI is not multiplexed on the HP PUSCH scheduled by the DCI.*** |
| vivo | ***Proposal 12: Semi-static indication and dynamic indication of intra-UE multiplexing and prioritization manner can be supported in Rel-17.***  ***Proposal 13: For dynamic indication, multiplexing or prioritization indicator filed can be included in DCI with HP or LP or both HP and LP.***  ***Proposal 14: For dynamic indication, a new field separately from priority indication can be included in DCI to indicate HP or LP channel to carry the multiplexed UCI.*** |
| Intel | **Proposal 9: DCI and higher layer indication can be provided to enable multiplexing of UCI onto DG PUSCH and CG PUSCH, respectively.** |
| Nokia | **Proposal 3.13: For the scenarios of multiplexing HARQ-ACK bits in DG PUSCH of different priorities,** gNB dynamically indicates via beta\_offset in the corresponding scheduling DCI whether to multiplex HARQ-ACK in PUSCH or not**. FFS whether to support multiplexing of HARQ-ACK bits on CG PUSCH of different priorities.** |
| Spreadtrum | 1. ***For HARQ-ACK multiplexing on PUSCH of different priority, support to set value of beta\_offset equals to zero to disable multiplexing.*** |
| IDC | ***Proposal 11: DCI scheduling HP PUSCH indicates if UE multiplexes LP HARQ-ACK in HP PUSCH.***  ***Proposal 12: DCI indicating HP HARQ-ACK also indicates if UE multiplexes HP HARQ-ACK in LP PUSCH.***  ***Proposal 13: A beta\_offset indicator field indicates if UE multiplexes LP HARQ-ACK in HP PUSCH.***  ***Proposal 14: RRC configuration for each HP CG configuration includes an indication of whether the UE can multiplex LP HARQ-ACK in corresponding HP PUSCH.***  ***Proposal 15: RRC configuration of SPS with HP HARQ-ACK includes an indication of whether the UE can multiplex HP HARQ-ACK in LP PUSCH.*** |
| Sony | **Proposal 8: The gNB dynamically indicates whether to enable/disable multiplexing of UCI bits into PUSCH of different L1 priorities.**  **Proposal 9: The “*beta\_offset indicator*” DCI field in the UL Grant scheduling the PUSCH is used to enable/disable multiplexing of UCI bits into PUSCH, where some of the indices are used to disable multiplexing.** |
| LGE | **Proposal #5: Prefer RRC configuration for the mechanism to enable/disable the multiplexing of HP HARQ-ACK and LP HARQ-ACK on PUCCH or the multiplexing of HARQ-ACK on PUSCH with different priority, with consideration of potential UE complexity and UCI/PUSCH reliability.** |
| TCL | **Proposal 6: Explicit indication for enabling UCI multiplexing on PUSCH with different priorities should be supported and configured by a new DCI field or RRC configuration.** |
| APT | Proposal 7 Dynamic indication is supported for indicating whether to multiplex overlapping high priority PUSCH and low priority PUCCH. FFS the indication method when semi-static beta offsets are configured. |
| Pana | **Proposal 10:**   * **For multiplexing a LP HARQ-ACK in a HP PUSCH (conveying UL-SCH only), enhancement of beta-offset values including , which allows for dropping LP HARQ-ACK should be supported.** |
| CMCC | **Proposal 16: Introduce new beta offset values smaller than 1 to limit the total resources assigned to LP HARQ-ACK in R17.**  **Proposal 17: For multiplexing HARQ-ACK on PUSCH of different priorities, RRC signaling and/or beta-offset=0 can be used for gNB enable/disable the multiplexing.** |
| ETRI | **Proposal 8: The scheduling UL-DCI has an additional field whether or not to allow multiplex HP UCI and LP UCI, or otherwise by the RRC signalling.** |
| Apple | **Proposal 3: For HARQ-ACK multiplexing on PUSCH of different priority in R17, RRC configuration is used to enable/disable the multiplexing.** |
| Sharp | **Proposal 9: RRC configuration is used to separately enable/disable of UCI multiplexing on PUSCH for each scenario.** |
| ITRI | Proposal 3:  For PUCCH multiplexed in PUSCH, beta\_offset configuration can be used to enable or disable the multiplexing. The multiplexing disabled if beta\_offset=0; otherwise the UE should perform the multiplexing.  Proposal 4:  For the case while both LP and HP UCIs are configured with dynamic beta\_offset indication, a dropping rule should be applied before performing the multiplexing if they are collided with a PUSCH. |
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## 1st round proposal and discussion

Proposal for 1st round discussion:

For HARQ-ACK multiplexing on PUSCH of different priority in R17, the multiplexing can be enabled by RRC configuration.

* FFS dynamic indication.

Support: DCM, QC, OPPO, Samsung, Pana, Sharp, ITRI, Apple, CATT, Lenovo/Moto, E///, LG, WILUS, Spreadtrum, TCL, HW, NEC, Xiaomi

Not support (should also agree on DCI indication now): Nokia, ZTE, Sony, IDC, Intel, vivo, APT

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| Company | Comments |
| DOCOMO | Support the proposal. |
| QC | Support FL proposal. RRC configuration is needed as baseline. |
| Nokia/NSB | Not support and need further clarification.  From our point of view, in case with DG PUSCH, since we already agreed to have separate configurations of beta\_offset, especially considering majority support of beta\_offset=0 which offers more flexibility comparing to RRC configuration, then it is not clear why RRC configuration is still needed. Considering CG PUSCH, the situation becomes more complicated and we propose RAN1 to further study the necessity of supporting multiplexing HARQ-ACK on CG PUSCH of different priorities. |
| OPPO | Support the proposal. |
| ZTE | Not fully support.  If the HARQ-ACK has the corresponding DCI, the multiplexing can be enabled by DCI indication as more scheduling flexibility at gNB side can be provided, otherwise the multiplexing can be enabled by RRC configuration. |
| Samsung | Support the proposal. Also, we support dynamic indication. |
| Panasonic | At least RRC configuration should be supported. Dynamic indication should further considered. |
| Sony | We do not support his proposal as it is. It isn’t clear if this proposal is to suggest that RRC configuration for multiple sets of beta values, where some beta values are re-interpreted as “No Multiplexing” or if we have a single RRC parameter that will enable/disable UCI & PUSCH multiplexing of different L1 priorities. |
| InterDigital | Support only in case there is no DCI associated to the HP transmission (either HP PUSCH or HP HARQ-ACK). Otherwise, multiplexing needs to be enabled in DCI associated to HP transmission. |
| Intel | Do not support. As mentioned previously in 2.3.2, after RRC configuration, DCI based enabling/disabling can be useful and provides more flexibility for handling the overlap in dynamic manner. |
| Sharp | Support |
| ITRI | Support |
| Apple | Support the proposal. RRC configuration should be the solution. |
| CATT | We support the proposal. |
| vivo | Do not support. Both RRC configuration and Dynamic indication should be supported. |
| Lenovo, Motorola Mobility | Support the proposal. |
| Ericsson | We support the proposal. But similar to others, both RRC and dynamic indication should be supported. |
| LG | We are supportive the proposal, and RRC configuration is to be baseline.  For other approaches, it seems to need more discussions on potential aspects/behavior such as misalignment between UE and gNB. |
| WILUS | Support. We also support dynamic indication. |
| Spreadtrum | Support |
| TCL | Partially support the proposal, considering the flexibility, DCI based indication should be considered. |
| Huawei, HiSilicon | Fine with the proposal. |
| NEC | Support the proposal. |
| ETRI | Both RRC and DCI can be supported. The UL grant can dynamically choose whether to multiplex because in some cases there is not sufficient resources to both UCI types. |
| Xiaomi | Support the proposal. And we think the solution for this issue should also keep unified as the discussion in section 2.3 UCI multiplexing of different priorities. |
| APT | Do not support. We think DCI indication (beta offset or other field) should be supported to dynamically indicate whether to do multiplexing. |

## Resource mapping

## Inputs from Tdocs

When no enough resource is left for LP HARQ-ACK.

* Option 1: The LP UCI is (partly or fully) dropped
  + Nokia, Sony, LGE
* Option 2: The LP UCI is compressed
  + OPPO, Nokia, LGE, QC

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 7: To support multiplexing UCI in one PUSCH when the UE would transmit multiple overlapping PUCCH and PUSCH with different priority, the following mechanisms should be supported to ensure the latency and reliability of high-priority information:***   * ***The timeline of ending symbols used for UCI transmission should be considered.*** * ***Beta-offset values and*** ***scaling factors should be separately configured for different priorities.*** * ***Low-priority HARQ-ACK should be compressed when the actual coding rate is higher than a threshold.*** |
| E/// | Proposal 3 In case of overlapping between PUCCH and/or PUSCH resources in a slot with different priorities, only UCI multiplexing methods on PUCCH or PUSCH resources that are extension of already existing UCI multiplexing methods are supported. |
| Nokia | **Proposal 3.15: For the scenarios where multiplexing low-priority HARQ-ACK in high-priority PUSCH, RAN1 to down-select the following options:**   * **Option 1: bundling of low-priority Type-2 HARQ-ACK bits.** * **Option 2: partial dropping of low-priority Type-2 HARQ-ACK bits.** |
| Sony | **Proposal 7: When multiplexing UCI bits into PUSCH of different L1 priorities, if there are insufficient REs in a PUSCH to carry the UCI bits, the LP UCI bits are dropped.** |
| LGE | **Proposal #13: Consider the bundling/dropping of LP UCI on PUSCH based on the maximum UCI coding rate as for the case of LP UCI on PUCCH.** |
| QC | ***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.**  ***Proposal 9:* When low priority HARQ-ACK overlap with high priority PUSCH, compress the low priority HARQ-ACK codebook into X bits before multiplexing on the high priority PUSCH.**   * **FFS details of compression scheme.** |
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## Timeline and latency requirements

## Inputs from Tdocs

**Latency requirement:**

* Option 1: Multiplexing is only allowed when the ending symbol of the LP PUSCH is no later than the ending symbols of PUCCHs carrying HP HARQ-ACK
  + HW, TCL
* Option 2: Multiplexing is only allowed when the ending symbol used for UCI transmission in a LP PUSCH is not later than the ending of HP PUCCH.
  + OPPO, HW?, Lenovo/Motorola Mobility
* Option 3: 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
* Option 4: Controlled by gNB by dynamic indication whether to multiplex LP with HP or not.
  + E///, Nokia/NSB

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 7: To support multiplexing UCI in one PUSCH when the UE would transmit multiple overlapping PUCCH and PUSCH with different priority, the following mechanisms should be supported to ensure the latency and reliability of high-priority information:***   * ***The timeline of ending symbols used for UCI transmission should be considered.*** * ***Beta-offset values and*** ***scaling factors should be separately configured for different priorities.*** * ***Low-priority HARQ-ACK should be compressed when the actual coding rate is higher than a threshold.*** |
| Huawei | ***Proposal 10: For HP HARQ-ACK overlapping with LP PUSCH, the multiplexing is only allowed when the ending symbol of the LP PUSCH is no later than the ending symbol of the PUCCH carrying HP HARQ-ACK.*** |
| CATT | ***Proposal 1: Multiplexing timeline should always be satisfied for overlapping channels with different priorities when multiplexing between UCIs with different priorities is supported.***  ***Proposal 2: For multiplexing of channels with different priorities, the multiplexing timeline is defined with reference to the start of a channel which would be used for multiplexing.***  ***Proposal 3: If the ending symbol of PUCCH or PUSCH for multiplexed UCI transmission is X symbols after the ending symbol of PUCCH for the higher priority UCI, LP channel should be dropped. FFS the value of X.*** |
| Nokia | **Proposal 3.14: For the scenario of the multiplexing between HARQ-ACK and PUSCH with different priorities, Rel-15 timeline conditions for multiplexing HARQ-ACK and PUSCH can be reused. If multiplexing timeline conditions are not fulfilled or no multiplexing is indicated from gNB, Rel-16 prioritization rule should be applied (i.e. the transmission of the low-priority channel(s) is cancelled)**. |
| LGE | **Proposal #16: Consider the mapping of HP HARQ-ACK starting from the first symbol in LP PUSCH with consideration of latency requirement for HP UCI.**  Proposal #19: Consider to introduce new timeline or offset in case of PUSCH collision handling with different priority. |
| TCL | **Proposal 7: Multiplexing for UCI and PUSCH with different priorities should only be allowed when the ending symbol of multiplexed PUSCH is no later than the ending symbol of high-priority UCI.** |
| Lenovo/Moto | **Proposal 6:** Study necessary changes in multiplexing timeline requirements to enable sub-slot based HARQ-ACK multiplexing in PUSCH. |
| CMCC | **Proposal 13: Multiplexing of HARQ-ACK into PUSCH with different priorities is allowed only if the following conditions are met:**   * **The existing Rel-15 timeline;** * **Latency check, i.e. for multiplexing of HP HARQ-ACK into LP PUSCH, multiplexing is performed only if the last symbol of PUSCH resource carrying multiplexed UCI and UL-SCH is not X symbol(s) later than the original PUCCH resource for HP HARQ-ACK;** |
| Xiaomi | ***Proposal 3: The R15 multiplexing timeline can be reused for PUCCH/PUSCH with different priorities.*** |
| QC | ***Proposal 15:* Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.** |
| Sharp | **Proposal 8: For HP HARQ-ACK on LP PUSCH, the timeline requirements and detailed multiplexing methods should be further studied.** |
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## Multiplexing scenarios, rules and order (incl. more than two overlapping channels)

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 1: The following scenarios of intra-UE collision should be supported in R17:***  ***HP HARQ-ACK/SR + LP HARQ-ACK/SR (if any) + CSI on PUCCH***  ***Proposal 9: For more than two overlapping channels, timeline and procedure for multiplexing and prioritization specified in 38.213 can be reused.*** |
| Huawei | ***Observation 1: For the multiplexing rule for the collision of more than 2 PUCCHs, the discussion should be delayed until the multiplexing rule for two colliding PUCCHs is agreed.*** |
| E/// | Proposal 10 For UCI multiplexing on PUSCH, one or more PUCCH can overlap with PUSCH where the corresponding UCI can be multiplexed in the PUSCH.  Proposal 17 For cases where a UCI overlaps with multiple PUSCHs, the PUSCH to be multiplexed with the UCI is determined based on signaling known to both gNB and UE.  Proposal 18 For cases where a UCI overlaps with multiple PUSCHs, RAN1 discuss the procedure for determining the PUSCH to be multiplexed with the UCI, taking into account the Rel-17 support of multiplexing UCI and PUSCH of different priorities. |
| Intel | **Proposal 7: CG-UCI is regarded as high priority and can be multiplexed in a similar manner as HP HARQ-ACK onto PUSCH.**  **Proposal 8: 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.**  **Proposal 13: 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 14: 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.** |
| NEC | ***Observation 1:*** *If the resource used for transmitting multiplexed HARQ-ACK feedback spans multiple sub-slots, there is a risk of losing a high priority HARQ-ACK due to collision of multiplexed transmission with another high priority PUCCH transmission in a later sub-slot.*  ***Proposal 1****: HARQ-ACK feedback multiplexing between different PUCCH resources not confined within a sub-slot is supported only if the latency requirements and timeline conditions are satisfied and the resulted PUCCH resource does not collide with a URLLC PUCCH resource in the second sub-slot.*  ***Proposal 6:*** *When multiplexing both low-priority HARQ-ACK and high-priority HARQ-ACK on a PUSCH scheduled by an UL non-fallback DCI with a DAI field, which HARQ-ACK codebook the DAI field is applied to should be configured by gNB.* |
| Nokia | **Proposal 3.17: Multiplexing high-priority SR in low-priority PUSCH is supported. FFS detailed ways of carrying high-priority SR information.**  ***Observation 3.4: Multiplexing of more than one PUCCH carrying HARQ-ACK on a PUSCH of different priority should not be supported, as the multiplexing is also not supported for the same priority.***  ***Observation 3.5: Multiplexing of more than one high-priority PUCCH, where one of them is carrying HARQ-ACK and the other one carrying SR, on a low-priority PUSCH could be supported.***  ***Observation 3.6: Potential multiplexing restrictions or partial UCI dropping for low-priority UCI of more than one overlapping PUCCH multiplexed on an overlapping high-priority PUSCH may be acceptable, whereas partial dropping or multiplexing restrictions of high-priority UCI is not acceptable.***  **Proposal 3.18: 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 important when considering the support of multiplexing of high-priority UCI on low-priority PUSCH.** |
| IDC | ***Proposal 1: Support multiplexing for following additional scenarios:***   * ***High-priority SR in a low-priority PUSCH (UL-SCH only)*** * ***High-priority SR and HARQ-ACK in a low-priority PUSCH (UL-SCH only)*** * ***High-priority SR in a low-priority PUSCH (UL-SCH + low-priority HARQ-ACK and/or CSI)*** * ***High-priority SR and HARQ-ACK in a low-priority PUSCH (UL-SCH + low-priority HARQ-ACK/CSI)***   ***Proposal 16: DCI scheduling PUSCH includes a single DAI value. In case both LP and HP HARQ-ACK are multiplexed in PUSCH, the DAI corresponds to HP HARQ-ACK only.***  ***Proposal 17: Support multiplexing of high-priority SR in PUSCH by selection of DMRS sequence in PUSCH.*** |
| LGE | **Proposal #14: Consider how to determine the priority of CG-UCI and how to encode the CG-UCI payload in case of UCI multiplexing on NR-U CG PUSCH with different priority.**  **Proposal #15: 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 #20: Consider enhanced collision handling between HP PUSCH and LP PUSCH with UCI piggybacking. |
| TCL | **Proposal 8: The scenario of multiplexing more than two overlapping channels should be further studied.** |
| APT | Proposal 5 CG-UCI multiplexed in a high priority CG PUSCH is treated as high priority HARQ-ACK and jointly encoded with high priority HARQ-ACK, if there is high priority HARQ-ACK to be multiplexed in the CG PUSCH. |
| Lenovo/Moto | **Observation 1:** Rel-16 NR allow UE to perform multiplexing of UCI including HARQ-ACK into a PUSCH based on a slot-based multiplexing framework. Thus, low-latency HARQ-ACK feedback may not be fully realized.  **Proposal 5:** Support multiplexing of multiple sub-slot based HARQ-ACK transmissions in a PUSCH spanning more than one sub-slot.  **Proposal 7:** In Rel-17 NR, support multiplexing of low priority SR, SR/HARQ-ACK, or HARQ-ACK without SR into a high priority PUSCH without UL-SCH.  **Observation 2:** For multiplexing high priority HARQ-ACK in low priority PUSCH, applying different beta offset values depending upon priority level might not be enough to satisfy low-latency requirement.  **Proposal 8:** 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. |
| Pana | **Proposal 1: The collision handling between high-priority SR and low-priority PUSCH should also be supported in Rel.17.** |
| ETRI | **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.** |
| Xiaomi | ***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.***  ***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.*** |
| QC | *Proposal 12:* Adopt the collision resolution in Table 6 for collision between different priority PUCCH/PUSCH transmissions.  Table 6. URLLC/eMBB UL transmission collision resolution   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | |  | LP SR on PUCCH | LP ACK on PUCCH | LP CSI on PUCCH | LP SR+ACK+CSI on PUCCH | LP PUSCH | LP ACK + CSI (+UL-SCH) on LP PUSCH | | HP SR on PUCCH | Drop LP SR | See Proposal 5,6 | Drop LP CSI on PUCCH | Drop LP PUCCH | Drop LP PUSCH | Drop LP PUSCH+ACK+CSI | | HP ACK on PUCCH | See Proposal 5,6 | See Proposal 2, 3, 4 | Drop LP CSI on PUCCH | Drop CSI, MUX compressed eMBB A/N, and SR on URLLC PUCCH | See Proposal 8. | See Proposal 10 | | HP SR+ACK on PUCCH | FFS | Compress LP A/N then MUX on URLLC PUCCH | Drop LP CSI on PUCCH | Drop CSI, MUX compressed eMBB A/N, and SR on URLLC PUCCH | Drop LP PUSCH | Drop LP PUSCH, i.e., drop UL-SCH+CSI, bundle LP HARQ-ACK and MUX on URLLC PUCCH | | HP PUSCH | Drop LP SR | See Proposal 9 | Drop LP CSI on PUCCH | Drop CSI and SR, MUX compressed LP A/N on HP PUSCH | Out of the scope of WID expect DG-PUSCH vs CG-PUSCH | Out of the scope of WID expect DG-PUSCH vs CG-PUSCH | | HP ACK+A-CSI (+ UL-SCH) on PUSCH | Drop LP SR | Compress LP A/N then MUX on URLLC PUSCH | Drop LP CSI on PUCCH | Drop CSI and SR, MUX compressed LP A/N on HP PUSCH | Out of the scope of WID expect DG-PUSCH vs CG-PUSCH | Out of the scope of WID expect DG-PUSCH vs CG-PUSCH | |
| WILUS | * ***Proposal 10. In case of HP-PUSCH or LP-PUSCH contains LP-HARQ and HP-HARQ, it should be discussed how to indicate the presence of LP-HARQ and/or HP-HARQ to be multiplexed and “beta offset” for LP-HARQ and/or HP-HARQ.*** |
| Samsung | **Proposal 9: Intra-UE multiplexing should be performed in the following order,**   * **Step1: Multiplexing PUCCH(s) and/or PUSCH(s) with the same priority index.** * **Step2: Multiplexing PUCCH(s) and/or PUSCH(s) with the different priority indexes.** |
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# 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 and #103-e meetings, 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.*

Agreements:

*Support PHY prioritization of overlapping high-priority dynamic grant PUSCH and low-priority configured grant PUSCH on a BWP of a serving cell in R17.*

* *FFS the related cancelation behavior for the PUSCH of lower PHY priority and other details.*
  + *First clarify what is the scope of this feature, e.g. if overlapping between more than 2 channels is considered.*
* *FFS the timeline requirements.*
  + *First clarify what is the behavior of Rel-16 UE in case of DG/CG/UCI overlapping, with and without uplink skipping enabled.*
* *FFS UE capability for this feature.*
* *Note: The main bullet has been agreed in the WID by RAN Plenary.*
* *FFS details*
* *Clarify R16 baseline if needed.*

## Collision handling between LP DG-PUSCH and HP CG-PUSCH

## Inputs from Tdocs

* Option 1: For collision between HP CG PUSCH and LP DG PUSCH, PHY layer can make the prioritization so that the UE is expected to transmit the CG PUSCH and cancel the overlapping DG PUSCH at latest from the first symbol that is overlapping with the CG PUSCH.
  + ZTE, HW, vivo, MTK, Nokia, CMCC, Samsung
* Option 2: 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.
  + Intel, Xiaomi

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 9:*** *For the overlapping between HP CG and LP DG, 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.* |
| Huawei | ***Proposal 12: For collision between HP CG PUSCH and LP DG PUSCH, PHY layer can make the prioritization so that the UE is expected to transmit the CG PUSCH and cancel the overlapping DG PUSCH at latest from the first symbol that is overlapping with the CG PUSCH.*** |
| E/// | Proposal 19 Maintain the same understanding as in Rel-16, i.e., in the collision scenario between CG and DG with same/different PHY-priority index, and only one transport block is delivered to PHY, PHY transmit on the grant for which a transport block is delivered and skip the transmission on the other grant. |
| vivo | ***Proposal 15: For collision handling between high priority CG and low priority DG, 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 the first overlapping symbol of the PUSCH corresponding to the configured grant at the latest.*** |
| MTK | Proposal 16: The UE is expected to transmit the HP-CG PUSCH and cancel the overlapping LP-DG PUSCH scheduled by the PDCCH starting at latest at the first symbol of the CG PUSCH. |
| Intel | **Observation 1: It may not be feasible to define a proper cancellation timeline that is testable since it may not be feasible to externally determine the exact timing when the MAC layer delivers the corresponding MAC PDU to PHY for the HP CG PUSCH.**  **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.** |
| Nokia | ***Observation 2.1: For the scenarios CG PUSCH vs. DG PUSCH of different PHY priorities, the aspects related to handling the cases where a PUCCH overlaps with at least one of the overlapping PUSCHs and the impact of uplink skipping can be discussed after reaching a conclusion on the related Rel-16 discussions.***  **Proposal 2.1: For the scenario high-priority CG PUSCH vs. low-priority DG PUSCH, it is up to UE implementation to ensure that the low-priority DG PUSCH is cancelled, at the latest, from the first symbol that is overlapping with the high-priority CG PUSCH.** |
| CMCC | **Proposal 18: For collision handling between high priority CG and low priority DG, UE is expected to transmit the PUSCH corresponding to the configured grant, and cancel the low priority DG-PUSCH at the latest, from the first symbol that is overlapping with the high priority CG-PUSCH.** |
| Xiaomi | ***Proposal 7:*** ***The case of HP CG-PUSCH overlapping with LP DG-PUSCH should be handled by UE implementation.*** |
| Samsung | **Proposal 12: 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.** |
| Apple | **Proposal 4: Clarify the Rel-16 UE behavior concerning DG/CG transmission.** |
| DCM | **Proposal 10:**   * *Wait for Rel-16 discussion outcome on DG PUSCH/CG PUSCH/UCI collision handling*   + *If only one MAC PDU is delivered to PHY for all the collision cases, no need to further discuss PHY prioritization between DG PUSCH and CG PUSCH with different priorities.* |
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## Collision handling between HP DG-PUSCH and LP CG-PUSCH

## Inputs from Tdocs

* Option 1: For the overlapping between LP CG and HP DG, 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.
  + ZTE, HW, vivo, MTK, CMCC, Samsung, Sharp
* Option 2: On top of Rel-16 cancellation time (N2+d1) for PUCCH/PUCCH or PUCCH/PUSCH collision, additional time d2 is needed (which results N2+d1+d2 in total cancellation time) for LP CG-PUSCH and HP DG-PUSCH collision resolution.
  + QC
* Option 3: Per UE capability.
  + Intel

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 10:*** *For the overlapping between LP CG and HP DG, 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 Tproc,2+d1 after the last symbol of the PDCCH with the DCI format scheduling the high priority channel.* |
| Huawei | ***Proposal 13: For collision between HP DG PUSCH and LP CG PUSCH, PHY layer can make the prioritization so that the UE is expected to transmit the DG PUSCH and cancel the overlapping CG PUSCH at latest from the first symbol that is overlapping with the DG PUSCH.***   * ***The UE expects to cancel the CG PUSCH no earlier than Tproc,2+d1 after the last symbol of the PDCCH scheduling the DG PUSCH,*** * ***The UE expects to transmit the DG PUSCH no earlier than Tproc,2+d2 after the last symbol of the PDCCH scheduling the DG PUSCH.*** |
| E/// | Proposal 16 For CA case, support PHY prioritization of overlapping high-priority dynamic grant PUSCH and low-priority configured grant PUSCH on different serving cells in R17. |
| vivo | ***Proposal 16: For collision handling between high priority DG and low priority CG, 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 Tproc,2+d1 after the last symbol of the PDCCH with the DCI format scheduling the high priority channel, where d1 is determined by a reported UE capability.*** |
| MTK | Proposal 17: 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. |
| Intel | **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.**   **Observation 2: Since cancelation/prioritization is taking place at PHY, UL skipping related considerations from Rel-16 may not apply to Rel-17 PHY prioritization between HP DG PUSCH and LP CG PUSCH.** |
| Nokia | **Proposal 2.2: 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 | Proposal #18: PHY prioritization for the case where low-priority CG-PUSCH collides with high-priority DG-PUSCH is not supported in R17. |
| CMCC | **Proposal 19: 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 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.** |
| Xiaomi | ***Proposal 8:*** ***For LP CG-PUSCH overlaps with HP DG-PUSCH, related cancelation behaviour for LP CG-PUSCH defined in R16 can be reused.*** |
| Samsung | **Proposal 13: 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.** |
| Apple | **Proposal 4: Clarify the Rel-16 UE behavior concerning DG/CG transmission.** |
| QC | ***Proposal 13:* On top of Rel-16 cancellation time (N2+d1) for PUCCH/PUCCH or PUCCH/PUSCH collision, additional time d2 is needed (which results N2+d1+d2 in total cancellation time) for LP CG-PUSCH and HP DG-PUSCH collision resolution. The additional number of OFDM symbols (d2) needed is listed in following table**  Table 8. d2 for LP CG-PUSCH and HP DG-PUSCH collision resolution   |  |  | | --- | --- | |  | d2 [symbols] | | **0** | **1** | | **1** | **2** | | **2** | **4** | | **3** | **8** |   ***Proposal 14:* For d1 defined for PUCCH vs PUCCH or PUCCH vs PUSCH cancellation with different priorities, support subcarrier spacing dependent d1 values. FFS exact d1 values for each subcarrier spacing.** |
| Sharp | **Proposal 10: For collision between a LP CG-PUSCH and a HP DG-PUSCH, the LP DG-PUSCH should be dropped before the first symbol overlapping with the HP CG-PUSCH transmission, but not before Tproc,2+d1 after the scheduling DCI of the HP DG-PUSCH.** |
| DCM | **Proposal 10:**   * *Wait for Rel-16 discussion outcome on DG PUSCH/CG PUSCH/UCI collision handling*   + *If only one MAC PDU is delivered to PHY for all the collision cases, no need to further discuss PHY prioritization between DG PUSCH and CG PUSCH with different priorities.* |
| Apple | Timeline relaxation can be considered. |

# 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.*

## How to trigger this function?

## Inputs from Tdocs

* Option 1: Simultaneous PUCCH and PUSCH transmission can be configured in one serving cell
  + OPPO, E/// (RRC enable + dynamically disable), MTK, ~~Nokia,~~ QC
* Introduce a UE capability to trigger the simultaneous PUCCH and PUCH transmission on different carriers.
  + DCM

Separate configurations

* OPPO: RRC for CC, and configured for HP PUCCH and LP PUCCH
* 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 | Proposals/observations from Tdocs |
| OPPO | ***Proposal 8: The following mechanisms should be supported for simultaneous PUCCH/PUSCH transmission:***   * ***Simultaneous PUCCH and PUSCH transmission can also be configured in one serving cell;*** * ***RRC signaling can separately configures simultaneous PUCCH and PUSCH transmission for HP PUCCH and LP PUCCH.*** |
| E/// | Proposal 14 Simultaneous PUCCH/PUSCH transmissions on different cells at least for inter-band CA is enabled by RRC configuration.  Proposal 15 When simultaneous PUCCH/PUSCH transmissions is enabled by RRC configuration, simultaneous PUCCH/PUSCH transmissions can be dynamically disabled. |
| MTK | Proposal 11: PUCCH/PUSCH transmission.  Proposal 12: The UE is to be configured separately for inter-band and intra-band simultaneous PUCCH/PUSCH transmissions.  Proposal 13: The UE is to be configured for simultaneous PUCCH/PUSCH separately for different priorities on transmissions.  Proposal 14: Simultaneous PUCCH/PUSCH transmissions is enabled based on specific conditions. E.g. LP-PUCCH carrying HARQ feedback. |
| Nokia | **Proposal 4.3: For UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission over different cells can be triggered via higher layer signalling (e.g. RRC signalling).** |
| LGE | **Proposal #17: Consider the framework designed in Rel-10 LTE-A as the baseline for supporting simultaneous transmission of PUCCH and PUSCH in Rel-17 NR.** |
| Samsung | **Proposal 11: For UCI to be multiplexed on a PUSCH, the following conditions should be satisfied.**   * **Simultaneous PUSCH and PUCCH transmission does not apply.** * **The PUSCH satisfies the reliability requirements of the UCI.** * **FFS potential solutions to ensure the reliability of UCI on a LP PUSCH.** |
| QC | ***Proposal 18:* 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 19:* 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** |
| DCM | **Proposal 11:**   * *Introduce a UE capability to trigger the simultaneous PUCCH and PUCH transmission on different carriers.*   **Proposal 12:**   * *Discuss the interaction between capabilities for two PUCCH groups and the new capability for simultaneous PUCCH/PUSCH transmission on different carriers.* |
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## 1st round proposal and discussion

Proposal:

Simultaneous PUCCH and PUSCH transmission can be RRC configured in one serving cell.

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| Company | Comments |
| DOCOMO | We support the proposal in general but would like to clarify the exact UE behavior on this. In our understanding, the support of simultaneous PUCCH/PUSCH is configured per CC by RRC. For example, there are 4 CCs and the simultaneous TX is enabled on CC#0/#1 but not on CC#2/#3. In this case, if the UE is scheduled on PUSCH on CC#0 and PUCCH on CC#1, UE can TX both PUSCH and PUCCH without multiplexing. Is it correct understanding? If so, we propose the following minor update to more clarify it is enabled/disabled per CC:  Proposal:  Simultaneous PUCCH and PUSCH transmission can be RRC configured ~~in one~~ per serving cell. |
| QC | Support FL proposal |
| Nokia, NSB | Do not support.  We also think this is unclear (so cannot agree this). The intention is to have PUCCH and PUSCH on a different serving cell (and not on the same)  Suggest to change: “For UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission over different cells can be RRC configured.” |
| OPPO | Support FL proposal |
| Samsung | Support in principle.  Suggest the following update  Updated Proposal:  Simultaneous PUCCH and PUSCH transmission can be RRC configured ~~in one~~ per serving cell.  FFS: dynamic indication |
| Intel | Support Nokia’s revised proposal |
| Sharp | Support FL proposal |
| ITRI | Support FL proposal |
| Apple | The wording clarification from Nokia is useful. |
| CATT | According to the agreements, we only agreed to support simultaneous PUCCH/PUSCH transmissions on different cells at least for inter-band CA and FFS for intra-band CA. So our understanding is that we only agreed that UE can support simultaneous PUCCH/PUSCH transmissions on different cells in different bands.  The intention of the proposal is not clear to us. |
| vivo | Support FL proposal |
| Lenovo, Motorola Mobility | Fine with the proposal. |
| Ericsson | OK with FL support but with Samsung update. |
| LG | First of all, it seems to need clarification on FL’s proposal, especially for the part of “in one serving cell”.  We prefer configuration of this simultaneous PUCCH+PUSCH per UE as in LTE, rather than per cell. If the above Nokia’s proposal is intended to configure per UE, then we are supportive with the Nokia’s proposal. |
| Spreadtrum | Support Samsung’s revised proposal |
| Huawei, HiSilicon | If we follow the previous agreement, the focus should be inter-band CA? therefore we agree with the change from Nokia. As to the support of PUCCH and PUSCH on the same serving cell, probably need inputs from RAN4 also.  Suggest to change: “For UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission over different cells can be RRC configured.” |
| Xiaomi | Agree with HW’s opinion. |

## 2nd round proposal and discussion

Proposal:

For UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission over different cells can be RRC configured.

* + FFS: dynamic indication

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| Company | Comments |
| QC | Support this proposal |
| Nokia, NSB | Support the proposal with the following update (restriction on different PHY priorities).  “For UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission of different PHY priorities over different cells can be RRC configured.  FFS: dynamic indication” |
| Huawei, HiSilicon | We are fine with it though we don’t see any motivation to have dynamic indication. |
| LG | We support the proposal with assumption that simultaneous PUCCH/PUSCH transmission can be configured per UE basis (not per cell). |
| Sony | Support |
| Sharp | Support |
| DOCOMO | Support the proposal. Regarding the restriction suggested by Nokia, we think it is not needed for this proposal. The reason is the target of this proposal is to determine the triggering scheme not to determine whether simultaneous PUCCH/PUSCH TX is supported of same priority or different priorities. If we add the restriction here, we may need another proposal for triggering method for same PHY priority case. Probably, it would be better to discuss the supported priority case separately from this proposal. |
| vivo | Support the proposal. |
| QC2 | To Nokia: simultaneous PUCCH/PUSCH transmission already agreed on inter-band CA without any restriction mentioned in the agreements. The suggested modification reverts existing agreements. |
| CATT | We support the proposal. It seems to us that if a UE is capable of transmitting PUCCH and PUSCH with different PHY priorities over different cells, the UE is also capable of transmitting PUCCH and PUSCH with same PHY priority over different cells so that it is not quite clear whether we need to restrict to different PHY priorities only. |
| Spreadtrum | Support |
| ITRI | Support this proposal |
| LG | We agree with QC that simultaneous PUCCH/PUSCH transmission was agreed to be supported per UE basis, not per combination of priorities, thus the corresponding RRC configuration is also to be done per UE basis accordingly. |

## Agreed proposals

Agreements:

Per UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission of different PHY priorities over different cells can be RRC configured within the same PUCCH group

* FFS: dynamic indication

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

## Inputs from Tdocs

* Support.
  + vivo (as optional UE feature), MTK (for some cases), Intel, Samsung (no need to differentiate between intra-band CA and inter-band CA)
  + 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 | Proposals/observations from Tdocs |
| vivo | ***Proposal 17: Simultaneous PUSCH and PUCCH transmission can be supported for intra band CA case. This function can be an optional UE feature.*** |
| MTK | Proposal 9: 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 10: 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. |
| Intel | **Proposal 15: 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.**   **Observation 3: Although UE may support simultaneous transmission over different carriers for intra-band CA based on capability signaling, the scope may be limited such as simultaneous transmissions may only be possible when their durations are aligned.** |
| Nokia | **Proposal 4.1:** **The simultaneous transmission of PUCCH and PUSCH on different serving cells is applicable only for the case when PUCCH and PUSCH are of different PHY priority.**  **Proposal 4.2: For intra-band CA, simultaneous transmission of PUCCH and PUSCH on different cells is not supported.** |
| Samsung | **Observation 2: In RAN1 specifications, there needs to be no differentiation between intra-band CA and inter-band CA for simultaneous PUSCH and PUCCH transmissions from a UE.** |
| Apple | **Proposal 5: Simultaneous PUCCH/PUSCH transmission for intra-band CA is not supported.** |
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## Support simultaneous PUSCH/PUCCH transmission on a same cell?

## Inputs from Tdocs

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| Company | Proposals/observations from Tdocs |
| Pana | **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.** |
| Samsung | **Proposal 10: Send an LS to RAN4 to inquire about the feasibility/MPR for simultaneous PUCCH and PUSCH transmissions on a same cell.** |
| Apple | **Proposal 6: Simultaneous PUCCH/PUSCH transmission on the same CC is not supported.** |
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# Conclusion

# References

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