3GPP TSG RAN WG1 #104b-e R1-2103868

e-Meeting, April 12th – April 20th, 2021

Source: Moderator (OPPO)

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

Agenda Item: 8.3.3

Document for: Discussion and Decision

# Introduction

In this paper, discussions under the following email thread in RAN1#104b-e are summarized.

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

* 1st check point: 4/15
* 2nd check point: 4/19
* 3rd check point: 4/20

# 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.*

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*

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*

Agreements:

*When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, further study the following options (proponents are encouraged to provide more details and analysis):*

* *Opt.1: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource.*
  + *Opt.1a: The UE does not transmit negative SR.*
  + *Opt.1b: For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.*
  + *Opt.1c: For negative SR, the UE transmits SR and HARQ-ACK on the SR resource*
  + *FFS: whether with power boost to transmit multiplexed payload or not.*
* *Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.*
  + *Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.*
  + *Opt.2b: Using 4 CS values as for SR+1-bit HARQ-ACK in Rel-15/16. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.*
  + *Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.*
* *Opt.3: No enhancement over Rel-16.*
* *Other options not excluded.*
* *FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?*

Agreements:

*When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, further study the following options (proponents are encouraged to provide more details and analysis):*

* *Opt.1: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource.*
  + *Opt.1a: The UE does not transmit negative SR.*
  + *Opt.1b: For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.*
  + *Opt.1c: For negative SR, the UE transmits SR and HARQ-ACK on the SR resource*
  + *FFS: whether with power boost to transmit multiplexed payload or not.*
* *Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.*
  + *Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.*
  + *Opt.2b: Applying QPSK for SR+1-bit HARQ-ACK. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.*
  + *FFS on conditions of multiplexing.*
* *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, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.*
* *Opt.5: No enhancement over Rel-16.*
* *Other options not excluded.*
* *FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?*

Agreements:

*When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, further study the following options (proponents are encouraged to provide more details and analysis):*

* *Opt.1: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource.*
  + *Opt.1a: For positive SR, the UE transmits the PUCCH in the resource using PUCCH format 1 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.1b: SR and HARQ-ACK are multiplexed and modulated to be transmitted on the SR resource*
* *Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.*
  + *Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.*
  + *Opt.2b: Using 4 CS values as for SR+1-bit HARQ-ACK in Rel-15/16. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.*
  + *Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.*
  + *Opt.2d: HP SR and LP HARQ-ACK are multiplexed by the Rel-15 cyclic shift only if latency requirement for HP SR is met. Otherwise, drop the LP HARQ-ACK and only transmit the HP SR on its 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: No enhancement over Rel-16.*
* *Other options not excluded.*
* *FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?*

## 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 (incl. with compression for the LP HARQ-ACK).
  + **(2 simulations)** OPPO, MTK, Xiaomi, **Intel, QC,** Leno/Moto
* Option 2: Separate coding.
  + **(5 simulations) HW,** Spreadtrum, **ZTE, vivo,** APT, **E///, Nokia,** CMCC, **Samsung,** Sony, ETRI, WILUS
* Option 3: Separate coding and joint coding are both supported under some condition.
  + **(3 simulations) CATT, IDC,** Quectel, Apple (reuse Rel-15/16 encoding chain), Pana, LGE, Sharp, DCM, **QC**
* Option 3a: HP and LP HARQ-ACKs are multiplexed as in Fig 10 of [21], and HP HARQ-ACK is embedded in the LP HARQ-ACK codeword through spreading and OCC.
  + **QC**

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**Fig 10: A framework to multiplex the HP and LP HARQ-ACK on a same PUCCH/PUSCH.**

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

For multiplexing on a PUCCH format 0,

* Option 1: Treat the two bits as HARQ-ACK bits with HP priority and using R15 mapping rules.
  + HW, OPPO, ZTE, Intel, Pana, Samsung, Sharp, CATT
* Option 2: Support HARQ-ACK values to CS indices mapping with unequal distance between mapped CS indices.
  + **(1 simulation)** APT, **QC,** Pana

For multiplexing on a PUCCH format 1,

* Option 1: Treat the two bits as HARQ-ACK bits with HP priority and using R15 mapping rules.
  + HW, OPPO, ZTE, Intel, Pana, Samsung, CATT
* 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.
  + **(1 simulation) QC,** Pana

#### Simulations provided by Tdocs

**Huawei results:**

*Observation 1: For multiplexing HP HARQ-ACK and LP HARQ-ACK on PUCCH in case that the total number of bits is more than 2, separate coding can provide better reliability for HP HARQ-ACK with the SNR gain of about 2.5~6 dB.*







**ZTE results:**

|  |  |
| --- | --- |
|  | For 1bit HP UCI and 8bits LP UCI, the performance of separate coding with 5RBs is better than that of joint coding with 8RBs.   * For separate coding with 5RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -5.92dB, while the required SNR to satisfy BER@10^-2 for LP UCI is about -6.2dB. * For joint coding with 5RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -5.67dB. * For joint coding with 5RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -2.96dB. |
|  | For 4bits HP UCI and 6bits LP UCI, the performance of separate coding with 6RBs is still better than that of joint coding with 8RBs.   * For separate coding with 7RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -5.9dB while the required SNR to satisfy BER@10^-2 for LP UCI is about -6.83dB. * For joint coding with 8RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -5.43dB. * For joint coding with 7RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -4.80dB. |
|  | For 4bits HP UCI and 16bits LP UCI, the performance of separate coding with 6RBs is still better than that of joint coding with 8RBs.   * For separate coding with 6RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -4.0dB while the required SNR to satisfy BER@10^-2 for LP UCI is about -4.43dB. * For joint coding with 8RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -2.76dB. * For joint coding with 6RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -1.5dB. |
|  | For 10bits HP UCI and 10bits LP UCI, the performance of separate coding with 7RBs is still better than that of joint coding with 8RBs.   * For separate coding with 7RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -3.57dB while the required SNR to satisfy BER@10^-2 for LP UCI is about -4.84dB. * For joint coding with 8RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -2.81dB. * For joint coding with 7RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -2.05dB. |
|  | For 12bits HP UCI and 12bits LP UCI, the performance of separate coding with 7RBs is still better than that of joint coding with 8RBs.   * For separate coding with 6RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -2.95dB while the required SNR to satisfy BER@10^-2 for LP UCI is about -3.69dB. * For joint coding with 8RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -2.60dB. * For joint coding with 7RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about -1.64dB. |
|  | For 8bits HP UCI and 48bits LP UCI, the performance of separate coding with 6RBs is still better than that of joint coding with 8RBs.   * For separate coding with 6RBs: the required SNR to satisfy BER@10^-4 for HP UCI is about -0.89dB while the required SNR to satisfy BER@10^-2 for LP UCI is about -0.38dB. * For joint coding with 8RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about 0.23dB. * For joint coding with 6RBs: the required SNR to satisfy BER@10^-4 for HP UCI and BER@10^-2 for LP UCI is about 2dB. |

**vivo results:**



**CATT results:**

We propose that separate coding is supported. Besides, joint coding can also be supported at least for the case when HP HARQ-ACK or LP HARQ-ACK includes only 1 or 2 bits.



**IDC results:**

Table 1. Required SNR for separate vs joint coding.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 4HP/16LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | -4.8 | 2.8 | 0.9 | -1.9 | -2.6 | 6.3 | 3 | -3.3 |
| 70.0 | -4.1 | -1.8 | 2.7 | -1.8 | 1.5 | 1.5 |
| 50.0 | -3.3 | -3.8 | **4.2** | -0.6 | -0.5 | **3.5** |
| TDL300-C3 | 90.1 | -8.8 | 0.9 | -3.9 | -4.8 | -7 | 3.5 | -2.5 | -6 |
| 70.0 | -8.2 | -4.2 | 0.3 | -6.4 | -1.9 | -0.6 |
| 50.0 | -7.2 | -6.2 | **2.3** | -5.7 | -3.9 | **1.4** |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 10HP/10LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | -2.3 | -0.5 | 0.9 | 1.4 | -0.2 | 3 | 3 | 0 |
| 70.0 | -1.7 | -5 | **2.6** | 0.5 | -1.7 | **2.5** |
| 50.0 | -0.7 | -6.9 | 1.6 | 1.9 | -3.6 | 1.1 |
| TDL300-C3 | 90.1 | -6.7 | -2.6 | -3.9 | -1.3 | -5.3 | 0 | -2.5 | -2.5 |
| 70.0 | -5.9 | -7.3 | **2** | -4.6 | -4.9 | **2.1** |
| 50.0 | -4.9 | -9.2 | 1 | -3.5 | -6.8 | 1 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12HP/8LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | -0.3 | -1.5 | 0.9 | **1.2** | 2.1 | 2 | 3 | **0.9** |
| 70.0 | 0.4 | -5.8 | 0.5 | 2.3 | -2.4 | 0.7 |
| 50.0 | 1.5 | -7.7 | -0.6 | 4 | -4.3 | -1 |
| TDL300-C3 | 90.1 | -4.7 | -3.6 | -3.9 | -0.3 | -3 | -0.9 | -2.5 | -1.6 |
| 70.0 | -3.9 | -8 | **0** | -2.6 | -5.6 | **0.1** |
| 50.0 | -2.8 | -9.9 | -1.1 | -1.2 | -7.5 | -1.3 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12HP/12LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | -0.3 | 2 | 1.1 | -0.9 | 2 | 5.4 | 3.4 | -2 |
| 70.0 | 0.5 | -2.7 | **0.6** | 3.1 | 0.6 | **0.3** |
| 50.0 | 1.7 | -4.5 | -0.6 | 3.8 | -1.2 | -0.4 |
| TDL300-C3 | 90.1 | -4.9 | 0 | -3.5 | -3.5 | -3.3 | 2.5 | -1.7 | -4.2 |
| 70.0 | -4 | -5 | **0.5** | -2.2 | -2.8 | **0.5** |
| 50.0 | -2.8 | -6.9 | -0.7 | -0.9 | -4.7 | -0.8 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 8HP/48LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | -2.6 | 8.1 | 4.3 | -3.8 | 1.2 | 11.7 | 8 | -3.7 |
| 70.0 | -1.8 | 2.2 | 2.1 | 2.2 | 5.6 | 2.4 |
| 50.0 | -1 | -0.1 | **4.4** | 2.9 | 3.2 | **4.8** |
| TDL300-C3 | 90.1 | -7 | 6.6 | -0.8 | -7.4 | -5.5 | 9.4 | 1.1 | -8.3 |
| 70.0 | -6.4 | 0 | -0.8 | -4.7 | 2.5 | -1.4 |
| 50.0 | -5.4 | -2.5 | **1.7** | -3.7 | -0.2 | **1.3** |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12HP/44LP | % HP RE | BLER: LP 10-2, HP 10-4 | | | | BLER: LP 10-3, HP 10-5 | | | |
| HP | LP | Joint | Gain | HP | LP | Joint | Gain |
| TDL30-A3 | 90.1 | 0.4 | 7.6 | 4.3 | -3.3 | 3.9 | 11.2 | 8 | -3.2 |
| 70.0 | 1.1 | 1.9 | **2.4** | 5.2 | 5.2 | **2.8** |
| 50.0 | 2.2 | -0.4 | 2.1 | 5.8 | 2.9 | 2.2 |
| TDL300-C3 | 90.1 | -4.5 | 6.1 | -0.8 | -6.9 | -2.8 | 9 | 1.1 | -7.9 |
| 70.0 | -3.8 | -0.4 | -0.4 | -1.7 | 2.1 | -1 |
| 50.0 | -2.6 | -2.9 | **1.8** | -1.1 | -0.5 | **1.6** |



**Nokia results:**





**Intel results:**



**Qualcomm results:**

**For HP+LP HARQ-ACK bits =2:**



**Fig 3:** **Performance comparison between equal and unequal CS with PF 0**

Chart

Description automatically generated

Chart

Description automatically generated

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



**Fig 9: Performance comparison between separate encoding and joint encoding for 1 bit HP HARQ-ACK multiplexing with 1 bit LP HARQ-ACK**

**For HP+LP HARQ-ACK bits >2 (Separate coding vs. scheme in Figure 10 of [21]):**



**Fig 12: Performance comparison between separate encoding and proposed scheme for 1 bit HP HARQ-ACK multiplexing with 8 bits LP HARQ-ACK.**



**Fig 13: Performance comparison between separate encoding and proposed scheme for 1 bit HP HARQ-ACK multiplexing with 11 bits LP HARQ-ACK.**

**For HP+LP HARQ-ACK bits >2 (Separate coding vs. joint coding with HARQ-ACK compression):**



**Fig 14: Performance comparison between separate encoding and joint encoding for 1 bit HP HARQ-ACK multiplexing with 8 bits LP HARQ-ACK on a PUCCH**



**Fig 15: Performance comparison between separate encoding and joint encoding for 4 bit HP HARQ-ACK multiplexing with 8 bits LP HARQ-ACK on a PUCCH**

**Samsung results:**



#### Analysis on options

Table: Analysis recorded in the meetings

|  |  |  |  |
| --- | --- | --- | --- |
| **Analysis on Separate coding for HP HARQ-ACK > 2bits** | | | |
|  | | 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 | * Signal multiple coding rates for HP and LP HARQ-ACK on PUCCH (also need to signal multiple code rates for HP/LP UCI with different payload size). * New procedures need to be defined to perform separate coding and modulation * PUCCH resource (i.e., #RBs for PUCCH format 2 and 3) determination * RE mapping * 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 for HP HARQ-ACK > 2bits** | | | |
| 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 |  |
| **Analysis on unequal-distance CS allocation for HP HARQ-ACK > 2bits** | | | |
| Problems | Over-optimization | The current PUCCH format 0 can provide reliable transmission for 2-bit HP HARQ-ACK. No clear motivation to further enhance the reliability of HP HARQ-ACK through an unequal-distance CS allocation for HP HARQ-ACK bit state and LP HARQ-ACK bit state with respect to its implementation complexity. |  |

#### Proposals from Tdocs

|  |  |
| --- | --- |
| Company | Proposals/observations from Tdocs |
| Huawei | ***Observation 1: For multiplexing HP HARQ-ACK and LP HARQ-ACK on PUCCH in case that the total number of bits is more than 2, separate coding can provide better reliability for HP HARQ-ACK with the SNR gain of about 2.5~6 dB.***  ***Proposal 1: For multiplexing HP HARQ-ACK and LP HARQ-ACK on PUCCH in case that the total number of bits is 2 bits, the 1-bit HP HARQ-ACK and the 1-bit LP HARQ-ACK are concatenated and transmitted on PUCCH format 0 or PUCCH format 1 following the existing mechanism.***  ***Proposal 2: For multiplexing HP HARQ-ACK and LP HARQ-ACK on PUCCH in case that the total number of bits is more than 2, separate coding is adopted.*** |
| OPPO | ***Proposal 6: 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 7: No enhancement is supported for multiplexing of 1-bit HP HARQ-ACK and 1-bit LP HARQ-ACK on a PUCCH format 0/1.*** |
| Spreadtrum | 1. ***Support separate coding for multiplexing of HP HARQ-ACK and LP HARQ-ACK for total bit number being larger than 2.*** |
| ZTE | ***Observation 1:*** *The separate coding is beneficial in terms of resource efficiency when the two UCIs with different priorities will be transmitted in a same PUCCH.*  ***Proposal 1:*** *Adopt separate coding for the multiplexing of high priority UCI and low priority UCI on a PUCCH format 2/3/4 when the total payload of the UCIs is more than 2 bits.*  ***Proposal 2:*** *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.*   ***Proposal 3:*** *More things should be further studied, for example, the RE mapping scheme of HP and LP UCI coded bit, the compression/bundling/Partial dropping for LP UCI, after the separate coding scheme is determined.* |
| vivo | ***Observation 1: The BER performance of separate encoding is better than joint encoding.***  ***Proposal 3: Separate encoding is preferred for LP UCI and HP UCI multiplexing on PUCCH.***  ***Proposal 4: 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.*** |
| CATT | ***Proposal 8: 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 9: 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*** |
| 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. |
| APT | Proposal 1 Separate coding of high priority UCI and low priority UCI when multiplexed in a PUCCH is supported as a baseline.  Proposal 4 For multiplexing LP HARQ-ACK and HP HARQ-ACK on a PUCCH format 0, HARQ-ACK values to CS indices mapping with unequal distance between mapped CS indices should be supported. |
| IDC | ***Observation 1: Separate coding provides significant gain over joint coding in typical scenarios when the number of LP bits is larger than the number of HP bits (e.g. 4.8 dB for 8 HP/48 LP).***  ***Proposal 7: At least separate coding is supported when multiplexing LP and HP bits in PUCCH.***  ***Proposal 8: Support joint encoding of HP bits with a subset of LP bits when the number of HP bits is 1 or 2. FFS additional conditions.***  ***Proposal 9: Support joint encoding of LP bits with HP bits when the number of LP bits is 1 or 2.*** |
| E/// | [Proposal 9 Support separate encoding of high and low priority HARQ feedback in a PUCCH resource.](#_Toc68676149)  [Proposal 10 Study joint vs separate coding further for very small payloads.](#_Toc68676150) |
| 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 3.7: 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.** |
| Quectel | **Proposal 1**: Both separate coding and joint coding are supported when the total number of LP and HP HARQ-ACK bits is larger than 2. |
| CMCC | **Proposal 5: 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 6: For determining the code rates for HP UCI and LP UCI when multiplexing, two maxCodeRates can be configured for PUCCH resource used for multiplexing, one is used for LP UCI and the other is used for HP UCI.** |
| Xiaomi | ***Proposal 4: Support joint decoding for multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH.*** |
| Intel | **Observation 3:**   * **Separate coding requires significantly more standardization efforts compared to joint coding** * **Multiple channel encodings are performed for preparing one PUCCH for separate coding, causing increased UE complexity** * **The latency benefit for separate coding is questionable since receiver would have to wait until the DMRS symbols anyways before decoding** * **Joint coding can be built upon the legacy UCI multiplexing approach, which requires significantly less standardization efforts, is less complex and able to provide protection for HP HARQ-ACK, e.g., by LP HARQ-ACK payload reduction when needed.**   **Observation 4: Joint coding with LP HARQ-ACK payload reduction can match or outperform separate coding with reasonable resource split.**  **Proposal 3: When combined payload is 2 bits, multiplexing LP and HP HARQ-ACK bits follow Rel-15 approach assuming both bits are HP.**  **Proposal 4: Support joint coding of LP and HP HARQ-ACK payload bits when combined payload is more than 2 bits.**   * **LP HARQ-ACK payload bits can be partially dropped if needed** |
| Apple | **Observation 5-1: both joint encoding and separate encoding of UCIs are used in Rel-15 UCI multiplexing.** |
| Qualcomm | ***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 5*: In NR Rel-17,** f**or multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH/PUSCH, when the total number of LP and HP HARQ-ACK bits are more than 2 bits,**  **the HP and LP HARQ-ACKs are multiplexed according to the procedure in Fig 10**.   * **The high priority HARQ-ACK is embedded in the LP HARQ-ACK codeword through spreading and OCC.**   ***Proposal 6*: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK in R17, when the total number of LP and HP HARQ-ACK bits are more than 2 bits,**   * **Support compressing the LP HARQ-ACK payload prior to joint encoding of the HP and LP HARQ-ACK.** |
| Panasonic | **Proposal 2: 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 3: 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 4:**   * **For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH format 0, when the total number of LP and HP HARQ-ACK bits is 2 bits, either of the following options is supported.**   + **Option 1: Treat the two bits as HARQ-ACK bits with HP and using Rel.15 mapping rules.**   + **Option 2: Support HARQ-ACK values to cyclic shift indices mapping with unequal distance between mapped cyclic shift indices.** * **At least following factors should be considered for the decision of multiplexing scheme.**   + **The link performance in multi-user scenario**   + **Specification impacts**   **Proposal 5:**   * **For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH format 1, when the total number of LP and HP HARQ-ACK bits is 2 bits, either of the following options is supported.**   + **Option 1: Treat the two bits as HARQ-ACK bits with HP and using Rel.15 mapping rules.**   + **Option 2: Support transmitting the 2-bit HARQ-ACK values via two orthogonal sequences S1 and S2.**     - **S1 and S2 are generated based on the same base sequences S with different cyclic shift indices CS1 and CS2.**     - **1-bit is transmitted via sequence selection between S1 and S2, while other bit is transmitted using the selected sequence following legacy Rel.15 PUCCH format 1 with 1-bit payload.**   **Proposal 8: 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.** |
| Samsung | **Observation 1: Separate coding shows a gain over joint coding in case of RM coding.**  **Proposal 3: Support separate coding for UCIs with different priorities multiplexed on a PUCCH format 2/3/4 or a 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 both PUCCH format 0 and 1, modulation of 2 bits HARQ-ACK of a same priority can be reused.**   **Observation 2: Multiplexing of LP HARQ-ACK codebook and HP HARQ-ACK codebook with same and/or different HARQ-ACK codebook types can be enabled 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.** |
| Sony | **Proposal 1: The UCI bits of different L1 priorities are separately coded when multiplexing into a PUCCH.**  **Proposal 2: Allow encoded UCI bits of different L1 priorities to be mapped to different symbols in the PUCCH.** |
| ETRI | **Proposal 7: Separate coding in one PUCCH is supported.** |
| LGE | **Proposal #1: Support Option 3 (i.e., combination of joint coding and separate coding) for multiplexing of LP UCI and HP UCI on PUCCH with the total UCI payload size of more than 2 bits.**   * **Whether to apply joint coding or separate coding is determined according to UCI payload size of a priority or total UCI payload size of LP and HP.**   **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.**   **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).** |
| Sharp | **Proposal 9: 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.* |
| Leno/Moto | * **Proposal 3:** Support joint encoding of HP UCI with LP HARQ-ACK, if multiplexed in PUCCH of PUCCH formats 2, 3, and 4. |
| WILUS | * ***Proposal 1: We prefer to support the separate encoding for multiplexing UCIs of different priorities in a PUCCH.*** * ***Proposal 2: For multiplexing HARQ-ACK information with different priorities, TDM-ed mapping can be used to map UCIs with two priorities in a PUCCH.***    + ***The HARQ-ACK information with higher priority is mapped to the symbols preceding symbols for the HARQ-ACK information with lower priority.*** * ***Proposal 3: We propose to configure two maximum code rates per PUCCH format in the second PUCCH-Config, one for LP-UCI and the other for HP-UCI.*** * ***Proposal 6:***    + ***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) respectively***   + ***To multiplex with 1-bit LP-HARQ in PF1 and 1-bit HP-HARQ in PF1, reuse Rel-15 multiplexing rules without modification.*** * ***Proposal 7: To multiplex with HP-SR with PF0 and LP-HARQ with PF0, we propose,***    + *If HP-SR is negative, then transmit LP-HARQ on HARQ-ACK resource.*     - *In case of 1-bit LP-HARQ, use 2 CSs, i.e., {0, 6} CS index*     - *In case of 2-bit LP-HARQ, use 4 CSs, i.e., {0, 3, 6, 9} CS index*   + *If HP-SR is positive, then transmit LP-HARQ and HP-SR on HARQ-ACK resource*     - *In case of 1-bit LP-HARQ, use 2 CSs, i.e., {3, 9} CS index*     - *In case of 2-bit LP-HARQ, use 4 CSs, i.e., {1, 4, 7, 11} CS index*        * *To enhance HP-SR reliability, 2-bit LP-HARQ can be bundled to 1-bit and then the 1-bit bundled LP-HARQ is treated as 1-bit LP-HARQ, i.e., use 2 CSs, {3, 9} CS index .* |

## 1st round proposals and discussions

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 more than 2, support combination of separate coding and joint coding for the two HARQ-ACKs.

* + FFS the condition for applying separate coding and joint coding.
  + FFS how to multiplex the LP and HP HARQ-ACK after separate coding.
  + FFS HARQ-ACK compression/bundling for joint coding.

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, treat the two bits as HARQ-ACK bits with HP priority and using R15 mapping rules.

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 more than 2, support ~~combination of~~ separate coding and joint coding for the two HARQ-ACKs.

* + FFS the condition for applying separate coding and joint coding.
  + FFS how to multiplex the LP and HP HARQ-ACK transmissions for ~~after~~ separate coding.
  + FFS HARQ-ACK compression/bundling for joint coding.
  + FFS signaling mechanism to enable UE to perform separate coding only, joint coding only, or both for LP and HP HARQ-ACK multiplexing.

Support: QC, CATT, Quectel, DCM, NEC, Pana, ITRI, LG, Leno/Moto, Samsung, Spreadtrum, APT

Not support: Sony (combination is not clear), Nokia (separate coding only), OPPO (joint coding only), E/// (separate coding only), Intel (joint coding only), HW (separate coding only), vivo (separate coding only)

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, the baseline is to treat the two bits as HARQ-ACK bits with HP priority and ~~using~~use R15 mapping rules.

* + FFS multiplexing 1-bit SR with 1 (or 2) bit(s) A/N with different priorities.

Support: Sony, CATT, Quectel, DCM, NEC, Pana, Nokia, OPPO, E///, ITRI, Intel, LG, HW, Leno/Moto, Samsung, vivo, Spreadtrum

Not support: QC (not exclude enhancement over baseline), APT

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| --- | --- |
| Company | Comments |
| Sony | We agree with the proposal for UCI = 2 bits, i.e. treat the 2 bits as HP UCI and reuse Rel-15 mapping rules.  We cannot agree with the proposal for UCI > 2 bits as it isn’t clear how this combining of joint & separate coding is done. |
| QC | For the first proposal, although our preference is supporting joint encoding only, because of its simplicity and acceptable performance. But in principle, we are fine with this compromised proposal, because of its best performance among all the three options (See section 3.2.1 in R1-2103166). We suggest to add one more FFS on UE capability and RRC signaling in the proposal.  **Proposal 1**: 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 more than 2, support combination of separate coding and joint coding for the two HARQ-ACKs.   * + FFS the condition for applying separate coding and joint coding.   + FFS how to multiplex the LP and HP HARQ-ACK after separate coding.   + FFS HARQ-ACK compression/bundling for joint coding.   + FFS signaling mechanism to enable UE to perform separate coding only, joint coding only, or both for LP and HP HARQ-ACK multiplexing.   The 2nd proposal, unfortunately, is not acceptable to us, due to the following concerns.  Firstly, we think 1+1 bits UCIs with different priorities are the baseline for Rel-17 UCI mux. We don’t see the point to not enhance the baseline scenario but enhance the 1+X bits scenario. Also, according to Rel-17 URLLC WID “**Specify** multiplexing behavior among HARQ-ACK/SR/CSI and PUSCH for traffic with different priorities, including the cases with UCI on PUCCH and UCI on PUSCH”, both scenarios “1+1 bits” and “1 + >1” bits should be supported and specified, because the WID does not say only specify multiplexing behavior … for 1+ >1 UCIs with different priorities. The 2nd proposal contradicts with Rel-17 URLLC WID.  Secondly, we think a common design principle should be applied to multiplexing 1-bit HP A/N + 1-bit LP A/N, and multiplexing 1 bit SR + 1 or 2 bit A/N with different priorities, i.e., proposals in section 2.6. What is the different between 1-bit HP A/N + 1 bit LP A/N and 1-bit HP SR + 1 bit LP A/N? Again, based on the WID, we support enhancement both cases and we propose RAN1 should strive for a common design between these two cases.  **Proposal 2: strive for a common design between multiplexing 1-bit HP A/N with 1-bit LP A/N and multiplexing 1-bit SR with 1 (or 2) bit(s) A/N with different priorities.** |
| CATT | We agree with both of the proposals. |
| Quectel | For Proposal 1:  We are in principle fine with the proposal. However, we think it is ambiguous for “combination of separate coding and joint coding ”. It seems to us that separate coding and joint coding are always combined used. We could simply say “both separate coding and joint coding are supported”. Furthermore, we share similar view as QC that the selection of coding scheme could be configured by gNB (UE capability could be also used if deemed necessary) . The configuration signaling could be explicit or implicit (e.g., by configuring a parameter for the selection condition). The exact signaling design could be left open at this meeting. We prefer to use a more generic description for the signaling design. For joint coding, partial dropping (or shortening) could be another alternative to limit the number of LP HARQ-ACK bits. We suggest the following modifications.  **Proposal 1**: 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 more than 2, both separate coding and joint coding are supported for the two HARQ-ACKs.   * + FFS whether and/or how a condition for applying separate coding and joint coding is defined.   + FFS how to multiplex the LP and HP HARQ-ACK after separate coding.   + FFS HARQ-ACK compression/bundling/partial dropping for joint coding.   + FFS signaling mechanism for configuration of separate coding and/or joint coding.   For Proposal 2:  We agree this proposal. In our view, gNB can simply disable the multiplexing if the performance of HP HARQ-ACK would be degraded to an unacceptable level due to multiplexing. |
| DOCOMO | We agree with the both proposals for total UCI =2 bits and more than 2 bits. |
| NEC | We are fine with proposal 1 in principle. However, we agree with Quectel that it seems separate and joint coding are always combined. Therefore, it needs to be clarified in the revised proposal. We agree with QC that gNB can configure the coding scheme and the signaling design for this can be FFS.  We are fine with proposal 2. |
| Panasonic | We are fine with the first proposal. Even when the total number of payload size is large, there is possibility that when either the number of HP or LP HARQ-ACK bit is 1 or 2 bits, joint coding may be more appropriate coding scheme. If the combination is not agreeable, our preference is separate coding for the total number of LP and HP HARQ-ACK bits is more than 2.  On the second proposal, although our original proposal was either Option 1 or Option 2 is supported, we are fine with the FL proposal. For multiplexing on PUCCH format 0, although Option 2 provides better performance than Option 1 for HP HARQ-ACK, we are not sure whether Option 2 still provide better performance in multi-user multiplexing scenario. For multiplexing on PUCCH format 1, the disadvantage of Option 2 would be less resource efficiency (or multiplexing capacity) and degradation of LP HARQ-ACK performance. Considering specification/implementation point of view, the FL proposal seems acceptable. |
| Nokia/NSB | Do not support the first proposal (with >2 bits).  It’s preferable to agree on a single coding approach, as specifying a combination of both separated and joint coding would lead to increasing the specification efforts. Also, it would be difficult to specify the conditions for when to apply separate coding and when to apply joint coding.  Support the second proposal. |
| OPPO | Do not support the first proposal. Combination of separate and joint coding increases more spec workload and implementation complexity.  Support the second proposal. |
| Ericsson | 1st proposal: We do not support the first proposal as its current state and FFSs.   * The reason is that based on the proposed solutions, we are concerned the schemes proposing combination of separate and joint coding leads in additional complexity and implementation efforts which we are not convinced that are worth investing for this case when we have other options. * For the same reasons, we have mentioned repeatedly as NW vendor that for case of collision with LP HARQ-ACK, bundling/compression based solutions are not of interest for us. The reason is that it does not help the NW to understand the status of scheduled TBs in DL. Bundling/compression based techniques require new implementation. It should be justified for the NW to consider additional complexity, where in this case, the NW has other options to avoid the cost and achieve the expected performance.   2nd proposal: We are supportive of the proposal. Alternatively it is fine with us to drop LP HARQ-ACK in this case.  To clarify our view, specially in relation to aspects raised by QC:   * This proposal does not contradict WID. The WID was intended to retrieve LP HARQ-ACK in case of collision as it is subject to dropping in Rel-16. However. What it is important is WHY we are doing that. If during the work, we face situation that the solutions are too complex and not feasible, at least for some cases, we should be able to make adjustments. Secondly, the WID generally does not define the details, meaning that the outcome of the WI can as well be applicable to some cases, not all, with the conscious assessment of gain and complexity (in short, usefulness of the feature). * On comparison between these two cases:   + Case1(HP SR & 1-2 LP HARQ-ACK)   + Case2(1-2 HP A/N & 1-2 LP HARQ-ACK)   We would like to share our opinion as NW vendors why having a solution for Case 1 is important, but Case 2 not. The reason is that in case 1, the NW configures SR resources (very costly). Since the NW has no visibility when the SR is configured, if it has no means to multiplex HARQ-ACK with SR, it means that those configured resources would be solely dedicated to SR which is extremely costly for the NW. However, in case 2, for both HP and LP HARQ-ACK, the NW has full control how to utilize the corresponding resources. Therefore, these two cases are fundamentally different.  In short, our view is that before developing solutions for intra-UE multiplexing, it is important to keep aspects in perspective by understanding WHY we should do an enhancement and HOW we are doing an enhancement. If it is not costly, it is not worth to spend effort. Intra-UE multiplexing has become a monster feature already 😊 |
| ITRI | Agreed with proposal 2.  For proposal 1, the meaning of “combination of separate coding and joint coding” is not clear for us. Our understanding is that when the total number of LP and HP HARQ-ACK bits is more than 2, both separate coding and joint coding are supported for the two HARQ-ACKs |
| ZTE | Support the two proposals.  For the total number of LP and HP HARQ-ACK bits is more than 2, joint coding can be applied if number of the HP HARQ-ACK bits or LP HARQ-ACK bits is only 1 or 2, otherwise, separate coding is applied. |
| Intel | We do not support Proposal 1. As mentioned by few other companies, supporting both based on conditions makes this more complicated, more spec work, and this seems that we are spending too much time on optimization. It is better to support a single coding approach for > 2 bits. Our preference is joint coding among the two.  We support Proposal 2. |
| LG | We are supportive to Proposal 1 for more than 2 bits with condition that, the joint encoding means total payload of LP UCI and HP UCI is to be an input to a same encoder (rather than applying different way, e.g. OCC spreading).  We also support Proposal 2 for the case of 2 bits. |
| InterDigital | Support the proposals |
| Apple | In our contribution, we show it is possible to leverage the Rel-15 encoding chain to support joint encoding or separate encoding. Given the complexity of UCI multiplexing, we don’t feel it is to develop new rule for UCI multiplexing.  As for two bit UCIs, we propose to use a padding bit to “upgrade” the total bits to 3 bits, so to avoid complicated design with PF0/PF1. |
| Huawei | We do not agree with Proposal 1, i.e., the coding method for more than 2 bits.  By reviewing over the simulation results, we observed that most simulations show that the HP performance under the separate coding outperforms the joint coding, unless some more complicated methods are introduced for joint coding/hybrid coding, such as modified encoder, or compression/pruning of LP, which incurs more spec efforts and implementation complexity. On the other hand, the separate encoding can refer to the Rel-15 HARQ-ACK/SR/CSI part I and CSI part II rule which already adopts separate coding. In addition, the separate coding has the advantages of lower latency and higher robustness of HP HARQ-ACK under the LP DCI missing case as compared to joint coding.  For the combination of joint coding and separate coding, it means the network needs huge implementation effort to support both joint coding and separate coding to be compatible with various terminals. Therefore, we prefer to adopt separate coding as the single solution.  We agree with Proposal 2, i.e., the coding method for 1+1 bits. Before making the decision on whether to introduce an enhancement, we generally need to assess its value and cost. As per our knowledge, the backbone layer for the local URLLC are midband/highband TDD bands, including 2.6/4.9/3.5/26GHz, etc. The mainstream configurations include 4:1/8:2/7:3, which means for the most typical case there will be multiple PDSCHs pointing to one PUCCH, resulting the A/N payload to be more than 1. On the other hand, the network suffers huge implementation complexity on changing the bottom-layer operation of demodulation.  Therefore, we cannot see a strong value to introduce new modulation/sequence patterns for the case of 1+1 case, with respect to its non-trivial spec efforts and implementation complexity. |
| Lenovo, Motorola Mobility | We support the 2nd proposal (i.e. for HARQ-ACK up to 2 bits)  For the 1st proposal, we propose following modification:  To multiplex overlapping high-priority (HP) HARQ-ACK and low-priority (LP) HARQ-ACK transmissions in a PUCCH, when the total number of LP and HP HARQ-ACK bits is more than 2, support ~~combination of~~ separate coding and joint coding for the two HARQ-ACKs.   * + FFS the condition for applying separate coding and joint coding.   + FFS how to multiplex the LP and HP HARQ-ACK transmissions for ~~after~~ separate coding.   FFS HARQ-ACK compression/bundling for joint coding. |
| QC2 | On the 2 bits case:  To HW: In TDD band, those “4:1/8:2/7:3” DL/UL partition sounds like DL heavy. But it is from NW perspective. From UE perspective, we can not assume it has DL traffic in every DL slot. In light DL traffic scenario, multiplexing of 1+1 will occur. In heavy DL traffic scenario, multiplexing 1+ >1 will occur. Both are equally important scenarios.  Regarding the spec impact and implementation complexity of using different CS shift, it is not complicated at all, if we are willing to take a few minutes to think about the proposal. In spec, we just need to introduce a new set of CS indices. A new table is enough to capture it. On UE side, in stead of apply CS {0.3,6,9}, UE apply CS {0,1,6,7} to the sequence. On receiver side, instead of correlating received signal y with sequence with CS {0,3,6,9}, gNB correlate y with CS {0,1,6,7}. What is the difference in terms of hardware and software operation between these two operations? Most of the hardware and software operations are the same and can be reused from Rel-15 implementation. But the gain is significant.  To Panasonic: for the MU issue, with the new proposal, gNB can choose to not schedule MU to use adjacent CS indices. However, with the baseline, there is nothing gNB can do, because the even the SU performance suffer from the 3dB performance loss due to multiplexing. On the performance/implementation, please see comment above.  To Ericsson: between these two cases:   * + Case1(HP SR & 1-2 LP HARQ-ACK)   + Case2(1-2 HP A/N & 1-2 LP HARQ-ACK)   I see case 1 is less import to enhance. In case 1, gNB can always schedule the LP A/N around HP SR to avoid collision to begin with. In case 2, the HP A/N typically can not be further delayed to avoid collide with the previous scheduled LP A/N.  If we don’t enhance 1 bit HP + 1bit LP A/N, comparing with Rel-16, we just lose 3dB performance. If 3dB performance loss is acceptable, then I don’t see much need to debate between joint vs separate encoding for >2 bits case. Just reusing Rel-15 with joint encoding for >2 bits is enough, because in most of the cases, the performance gap between Rel-15 joint encoding and separate encoding is within 3dB.  Finally, even if we reuse Rel-15 for 1 + 1 case, to deal with the 3dB performance loss, at least a power boost/offset need to be added for the muxed payload. Please notice that in Rel-15 PUCCH format 0 power control equation, there is no power different between 1 bit or 2 bits payload. At least, as a minimum, we should fix this bug, by boost power by 3dB after mux the LP and HP bit.  On the >2 bits case:  We’d like to share some new results we just obtained with the group. If we just compare separate encoding with a simply joint encoding (without the OCC operatation), in case of 1 bit HP + 2 bits LP or 1 bit HP + 3 bits LP, the performance of separate encoding and joint encoding are almost the same. Just following what HW said, the typical DL/UL configuration is “4:1/8:2/7:3”, then 1+2 or 1+3 are typical use cases for UCI multiplexing. In these typical cases, we don’t see any benefit to do separate encoding. For other use cases such as 1+10 bits, if we follow the logic of not to do 1+1, we don’t see they are typical use case and we don’t want to pay to cost of spec impact and implementation complexity to support separate encoding for those cases. |
| Samsung | We would like to avoid optimizations for corner cases that have zero practical impact while requiring substantial specification complexity or, even worse, hardware changes to UE transmitter/gNB receiver. We can agree to the Proposal 1 only as a working assumption. We suggest the following update to make the proposal clear.  **Proposal 1**:  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 more than 2, support ~~combination of~~ separate coding and joint coding for the two HARQ-ACKs.   * + FFS the condition for applying separate coding ~~and~~ or joint coding.   + FFS how to multiplex the LP and HP HARQ-ACK after separate coding.   + FFS HARQ-ACK compression/bundling for joint coding.   Regarding the 2nd proposal for 2 bits, that is another corner case that will have zero impact on eMBB system throughput if not supported It requires all following conditions to be satisfied simultaneously.   1. 1 bit for LP HARQ-ACK 2. 1 bit for HP HARQ-ACK 3. 2 PUCCHs overlap in time 4. No overlapping PUSCH 5. Multiplexing is supported for LP HARQ-ACK and HP HARQ-ACK on a PUCCH.   For the above reasons, only simple solutions can be acceptable. We suggest the following update  **Proposal 2**:  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, treat the two bits as HARQ-ACK bits with HP priority and ~~using~~ use R15 mapping rules |
| vivo | For the 1st proposal: share the view with Nokia. It is very clear that in the most cases, the performance of separate coding is better than joint coding based on the simulation results. We prefer to support separate coding only for the case with more than 2bits for simplicity. Otherwise, it would be complexed to specify the conditions.  For the 2nd proposal: agree |
| Spreadtrum | Agree with the proposal for UCI = 2 bits.  For the first proposal, we think separate or joint coding should be separately configured/enabled, simultaneously joint and separate coding should be avoided to ease the implementation. |
| APT | We are fine with the first proposal.  We do not support the second proposal. The specification impact of using different CS shift is minimum and should be adopted in view of the performance gain. |

## 2nd round proposals and discussions

This issue is related to a trade-off between coding performance and implementation complexity. So it is essential to correctly understand the actual impact of the coding schemes to UE encoder implementation. According to the discussion in GTW session, there are different understandings on the UE implementation complexity across the group. Apple and Leno/Moto think that the R15 PUCCH encoding chain has supported separate coding for different types of UCIs, e.g. [20]:

* In no CSI report is of two parts, UCI multiplexing for HARQ-ACK, SR and CSI are jointly encoded.
* If at least one CSI report is of two parts, then CSI part 2 is separately encoded. And the rest are jointly encoded.

It is suggested to check the understanding with companies. Please provide your comments to the following observation.

Observation for 2nd round discussion:

Both joint encoding and separate encoding of UCIs are supported in Rel-15 UCI multiplexing**.**

* + Supporting separate coding or supporting both separate and joint coding for HARQ-ACKs with different priority in R17 UE does not bring a substantial UE implementation complexity increase over R15.

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| Company | Comments |
| Sony | It seems like CSI Part 2 is always separately code from the rest of the UCI. However, the proposal was to have LP HARQ-ACK and HP HARQ-ACK separately or jointly coded based on some conditions (which are yet to be defined). That is, LP HARQ-ACK can sometimes be jointly coded and sometimes be separately coded or a subset of the LP HARQ-ACKs are sometimes jointly coded and sometimes separately coded. I think this is higher level of complexity compared to the multiplexing case with two CSI parts. |
| QC | The comparison of UE implementation complexity between separate coding only vs separate+joint encoding depends on how to support separate+joint encoding. If support joint encoding for <=x bit payload and separate encoding for >x bits payload, then UE complexity is higher than support separate encoding only, because UE is enforced to implement both separate and joint encoding. If support separate+joint encoding based on UE capability report, then UE has flexibility report it can support only joint encoding, or only separate encoding, or both. With this UE capability signaling, a UE can choose to implement only joint encoding, or only separate encoding. Then UE complexity can be reduced.  Based on above reason, in the separate+joint encoding scheme, we don’t support to determine the coding scheme based on payload size. We support the other alternative to allow UE report capability to support which coding scheme(s). |
| Apple | Thanks to Jia to refer to our analysis, our main point is Rel-15/Rel-16 design is complicated enough, many aspects such as rate matching /RE mapping are complex already, let us reuse the existing design as much as possible.  Besides being complicated, Rel-15/Rel-16 design is also quite versatile. With a little adaptation, it can be used for inter-physical layer priority UCIm ultiplexing.  Our intention is not to give a blank check to either joint coding or separate encoding, rather when we talk about joint encoding/separate encoding, we don’t want depart too much from the Rel-16 design. In some way, we are treating existing design in NR as functional calls, we can discuss how to populate the inputs to those functional calls, without reopening the myriad of design choices as encountered in Rel-15.  Companies can clarify whether the Rel-15/16 design is sufficient. |
| Sharp | There are pros and cons on each coding method depending on the conditions.  Joint coding is simpler, but less resource efficient. Joint coding is better if the total payload is small at least in several cases.   1. For a codebook with 1 or 2 bits, there is no effective code but repetition. 2. For a codebook < 11 bits, RM code has no CRC with a 20-bit output, the actual coding rate and rate matching depends on the payload. If the total payload <= 11bits, joint coding with a single RM code may provide better performance. 3. If each codebook is smaller than 11 bits, but total payload > 11bits, joint coding can provide a CRC check.   Separate coding is better and more resource efficient when the payload size is big, esp. for LP HARQ-CAK.  Therefore, it is reasonable to support both coding methods, and further discuss the conditions of which coding method should be applied, e.g. payload threshold etc.  As a compromise, with two coding method specified, the gNB can configure the coding method by higher layer signaling | |
| Lenovo, Motorola Mobility | In Rel-15, when UCI is multiplexed in PUCCH, up to 2 separate UCI encodings are performed (HARQ-ACK/SR/CSI-part1 and CSI-part2). Since a PUCCH resource for CSI is considered as a low priority and is not multiplexed with HP UCI, HP HARQ-ACK/HP SR and LP HARQ-ACK can be separately encoded without increasing complexity. Thus, we don’t think UE capability indication is necessary. |
| DOCOMO | We think both joint encoding and separate encoding are supported in Rel-15. In Rel-15/16, up to two separately coded UCI parts for UCI on PUCCH, and up to three separately coded UCI parts for UCI on PUSCH are supported. If Rel-17 intra-UE multiplexing for different priorities is not introduced for CSI, the UE complexity in terms of polar encoder will not be increased. At RAN1#102-e meeting, we agree to deprioritize the discussion on multiplexing for CSI and thus Rel-17 intra-UE multiplexing would not be introduced for the CSI case. Therefore, we agree the observation. |
| Samsung | Agree in principle. We would like to clarify that only separate coding is supported in the PUSCH. |
| Quectel | In our view, the complexity mainly depends on the maximum number of channel encoders that a UE is required to simultaneously operate by the specification.  In Rel-15/Rel-16   * PUCCH: two channel encoders, one encoder for HARQ-ACK+SR+CSI part I and one encoder for CSI part II; * PUSCH: four channel encoders, one encoder for HARQ-ACK(+CG-UCI introduced by Rel-16), one encoder for CSI part I, one encoder for CSI part II, and one encoder for UL-SCH;   For separate coding of HP HARQ-ACK and LP HARQ-ACK, if the LP HARQ-ACK cannot leverage the existing encoder for CSI part II, an extra channel encoder may be required to simultaneously operate compared to Rel-15/Rel-16, which certainly will increase the complexity. If the LP HARQ-ACK can reuse the existing encoder for CSI part II, the LP HARQ-ACK may has to be jointly encoded with CSI part II when CSI part II is configured. In this sense, LP HARQ-ACK has to be jointly encoded with HP HARQ-ACK or with CSI part II. If jointly encoded with CSI part II, the coding rate adjustment for LP HARQ-ACK (e.g., by bundling/compression) is also needed even for separate coding. The argument against the joint coding could apply also for the separate coding. One may argue that CSI part II could be dropped or multiplexing of CSI part II and LP HARQ-ACK is not supported. However, this obviously degrades the HP CSI accuracy or largely limit the multiplexing flexibility as HP period CSI or SPS CSI is carried by the HP PUCCH (the discussion of AP-CSI carried by PUCCH is still ongoing). It is also worth being noted that an extra encoder may still be required even assuming CSI part II does not exist, if the number of LP HARQ-ACK bits is small (such as <12bits), in which case, a new block coding or a new RM coding is required. The block coding for 1 or 2 bits is only supported for UCI on PUSCH in Rel-15/Rel-16. Addition of a new block coding chain for PUCCH is not desired.  We fully agree with QC that payload size should not be the only condition to choose between separate coding and joint coding. It may also depend on whether existing channel encoder can be leveraged and whether a UE has the capability to support an extra encoder. |
| InterDigital | Agree with the observation. For the dependency of coding scheme based on payload size, it seems that the UE already needs to deal with this (e.g. because of using polar code for payloads above 11)? |
| vivo | Agree with the observation for R15 UCI encoding. But it doesn’t mean supporting both separate and joint coding for HARQ-ACKs with different priority in R17 UE does not bring a substantial UE implementation complexity increase over R15. Since LP HARQ-ACK can be multiplexed with CSI before multiplexed with HP HARQ-ACK, there are different cases:   1. HP HARQ-ACK +LP HARQ-ACK 2. HP HARQ-ACK+LP HARQ-ACK+ CSI with part 1 only 3. HP HARQ-ACK+LP HARQ-ACK+ CSI part 1+ CSI part 2   If 3) is supported, and separate encoding for HP HARQ-ACK and LP HARQ-ACK is used, the separate encoding chains will be increased to 3, which will have impact on UE implementation complexity.  We can agree on the maximum number of separate encoding UCI on PUCCH first. If 2 is kept, in case 3), we can support to drop CSI part 2.  We prefer to support single encoding scheme, and separate encoding is preferred considering its performance gain. We can accept to support joint encoding and separate encoding based on UE capability, we think its too complexed to support joint encoding or separate encoding based on other conditions, such as HARQ-ACK payload. |
| ITRI | Thanks FL for the analysis, and we agree with the observation. In current specification, up to 2 separate coding is supported for different UCI parts in PUCCH, and only separate coding is supported in the PUSCH. In addition, the coding scheme is determined according to the payload size. Therefore, I think the implementation complexity for the encoding is not a big issue regardless of supporting separate coding or supporting both separate and joint coding for the HARQ-ACKs with different priorities. |
| Intel | Agree with main bullet. However, we think the observation captured in sub-bullet is not that straightforward. It maybe true for only when 1) two encoders are used, 2) PF 3 and PF 4 are used. For PF2, only joint coding is used in Rel-15.  Note that complexity of the design maybe similar to Rel-15 with above conditions but the imminent large specification impact should also be one of the most important factor. |
| Intel | RRC indication is fine for consideration of e.g., CG-PUSCH. For DG-PUSCH, DCI indication is preferred. Similar comment as IDC, the argument on UL grant coming later than DL grant is not clear. |
| Nokia/NSB | In Rel-15 NR, both separate and joint encoding are supported.  We don’t support the proposal after the first round of discussion.  As we already stated, we still prefer to agree on a single coding approach, as specifying a combination of both separated and joint coding would lead to increasing the specification efforts, particularly since it would be difficult to specify the conditions for when to apply separate coding and when to apply joint coding. Moreover, as proposed by the moderator in the GTW session to have the joint or separate coding as a UE capability would lead to fragmentation in the market increasing gNB implementation efforts (please note, it is not just all about UE complexity). Therefore, we prefer to select a single coding scheme and we support separate encoding as for most of the cases, based on the simulation results, the performance of separate coding is better than joint coding. |
| LG | Agree in principle with the observation.  As commented in GTW, there seems to be no difference in terms of complexity between the case of joint encoding for LP+HP and the case of encoding for HP only if there is no LP. Thus, it may not be expected that complexity with combination of separate + joint coding would be increased compared to separate coding only.  Nevertheless, if companies are having serious concern to have two coding schemes and if we have to choose a single coding scheme, we slightly prefer separate coding only option with consideration of UL resource efficiency. |
| ZTE | Agree with the observation. We prefer both separate coding and joint coding. |
| Huawei | As we commented in the last meeting, most simulation results showed that HP performance under separate coding outperforms that of joint coding; even for joint coding funs, the joint coding results and the HP under the separate coding are very close, unless more enhancements are applied to joint coding such as more complex encoder or LP compression/pruning. However, such enhancements on joint coding largely unavoidably increases the implementation complexity. Therefore, we cannot observe an application case where the R15 based joint coding, w/o introducing extra enhancements, can outperform separate coding on HP performance.  In addition, even either the separate coding or R15 based joint coding does not bring a substantial UE implementation complexity, we would not prefer to support both in parallel, e.g., based on payload size or other dynamically switching way.  However, for the progress, we agree the observation with the following necessary modifications (marked in red).  “  Supporting separate coding or supporting ~~both separate and~~ R15 based joint coding without enhancement for HARQ-ACKs with different priority in R17 UE does not bring a substantial UE implementation complexity increase over R15.  ” |

## 3rd round proposals and discussions

Based on the 2nd round discussion, it seems clear that R15 has supported different coding schemes (i.e. joint coding, separate coding, joint+separate coding) for NR-PUCCH. Hence it is suggested not to consider the UE implementation complexity as a factor for selecting the coding scheme for multiplexing between HP and LP HARQ-ACK. Then if only taking into account the coding performance and standardization efforts, based on the simulation results from companies in this meeting, it seems separate coding only is the best choice. Thus the following conclusion and proposal are suggested by the FL. The views from companies are welcome.

Conclusion for 3rd round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, choose the encoding scheme (e.g. joint coding vs. separate coding) only considering the coding performance and the standardization efforts.

* + Note: Both joint encoding and separate encoding of UCIs are supported in Rel-15 UCI multiplexing**.**

Proposal for 3rd 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 more than 2, support separate coding for the two HARQ-ACKs.

* + FFS details for multiplexing.
  + FFS HARQ-ACK compression/bundling.

Proposal for 3rd 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, the baseline is to treat the two bits as HARQ-ACK bits with HP priority and use R15 mapping rules.

* + FFS multiplexing 1-bit SR with 1 (or 2) bit(s) A/N with different priorities.

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| Company | Comments |
| Sony | Disagree with the Conclusion. CSI 2 is always separately encoded in Rel-15/16. In contrast the original proposal suggested some undefined conditions whether LP HARQ-ACK is jointly or separately encoded, which is difficult to agree because the conditions can make things complex.  However, we **agree with the 2 proposals** since it is clear that the said condition is only about whether UCI = 2 bits or not. |
| OPPO | Although separate coding and joint coding has been supported in Rel-15/16. However, to support Rel-15/16 solution, up to two channel encoders are required for PUCCH and up to four channel encoders are required for PUSCH. So, to avoid UE implementation complexity, restriction of encoder number should be added. So, we suggest to add sub-bullet in conclusion.  Conclusion for 3rd round discussion:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, choose the encoding scheme (e.g. joint coding vs. separate coding) only considering the coding performance and the standardization efforts.   * + Note: Both joint encoding and separate encoding of UCIs are supported in Rel-15 UCI multiplexing**.**   + Maximum number of required encoding pipeline keeps the same as Rel-15/16. |
| LG | Our original preference is the combination of joint + separate coding according to the condition of LP/HP UCI payload size. But, as Sony mentioned, it would be difficult to make a common condition even among the proponents.  In this context, we can live with the above two proposals, for the progress. |
| Huawei | In principle agree with the two proposals. As we mentioned in the 2nd round, the joint coding w/o further enhancement (enhanced encoder/LP compression) is no better than the separate coding in terms of the HP performance. In addition, the separate coding also outperforms joint coding from the perspectives of latency and robustness of missing HP DCI. Therefore we can hardly see a use case for which the joint coding should be applied.  Yet we have two clarification questions:  1) FFS: HARQ-ACK compression/bundling, under proposal 1, is not clear for us: in what case shall the HARQ-ACK (LP?) under the separate coding be compressed/bundled?  2) FFS: multiplexing 1-bit SR with 1 (or 2) bit(s) A/N with different priorities. We think it should be discussed in section 2.6? |
| InterDigital | We think multiplexing a subset of LP bits with HP bits could be beneficial in some conditions, but OK with proposal for progress.  Prefer to remove the FFS on HARQ-ACK compression. |
| Apple | Note it is not implementation complexity is not a concern (which is always a concern!), rather we don’t necessarily assume separate encoding is more complex than joint encoding. So for Proposal 1 we suggest wording change as:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, choose the encoding scheme (e.g. joint coding vs. separate coding) ~~only~~ considering the coding performance and the standardization efforts and implementation complexity.   * + Note: Both joint encoding and separate encoding of UCIs are supported in Rel-15 UCI multiplexing**.**   + The maximum number of required encoding chains of UCIs with or without UCI types other than HARQ-ACK in Rel-17 is the same as Rel-15/16.   For Proposal 2, we suggest wording change as:  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 more than 2, support separate coding only for the two HARQ-ACKs.   * + FFS details for multiplexing.   + FFS HARQ-ACK compression/bundling.   + The maximum number of required encoding chains of UCIs with or without UCI types other than HARQ-ACK in Rel-17 is the same as Rel-15/16.   Proposal 3 can be clarified (In Rel-15/16, we don’t have HARQ-ACK multiplexing from two colliding PUCHs) |
| Panasonic | On the proposed conclusion, we share similar view with OPPO and Apple, From implementation complexity perspective, the number of encoder (especially Polar encoder) may also be considered.  Although our original preference is combination of joint coding and separate coding, based on the other companies’ view, we see it would be difficult to make common condition and agree it. Therefore, we can live with separate coding only. For the first proposal, we are fine with Apple’s suggestion. For the second proposal, we share Huawei’s comment. FFS point should be discussed in Section 2.6. |
| Samsung | Support the first proposal.  Do not support the second proposal. Nothing is needed for such scenario and Rel-16 remains applicable. |
| ZTE | Fine with the 2 proposals.  For the FFS: multiplexing 1-bit SR with 1 (or 2) bit(s) A/N with different priorities, maybe it doesn’t belong to this section? |
| QC | Disagree with the Conclusion. Supporting separate coding for HP + LP A/N definitely increases UE complexity. We don’t know based on what observation this conclusion is drawn. Yes, Rel-15 joint encoding A/N+CSI-1, and separately encode CSI-2. But now A/N has two priority and if they are separately encoded, how come this will not increase UE implementation complexity. Support joint encoding LP +HP A/N following Rel-15 coding scheme will not increase UE complexity.  Disagree with proposal 1, from standard impact point of view, separate encoding has huge spec impact. From performance point of view, we already provided results in 1st round of email discussion to show with 1+2 and 1+3, a simple joint encoding has same performance as separate encoding. With 1+>3 bits, joint encoding (use OCC to embed HP on encoded LP) has better performance than separate encoding. Without see any benefit of separate encoding, we object proposal 1.  Disagree with proposal 2, even if we choose not to do any optimization for 1+1 bits payload, reuse Rel-15 is not acceptable due to loss of 3dB performance for the HP. Instead, we should use Rel-16 as baseline, which at least guaranteed HP bit performance. Or we take Rel-15 solution, but at least introduce a power boost to compensate the 3dB performance loss for HP bit |
| Quectel | We disagree with the conclusion that implementation complexity is not considered for the encoding scheme design.  We do not support the first proposal (i.e., separate coding only for more than 2 bits).  **Implementation complexity**: In our view, repetition coding and simplex coding are only supported for 1 or 2 bit UCI on PUSCH in Rel-15/Rel-16. We would have to design and specify these two encoders also for PUCCH if only separate coding is supported (in case of 1 or 2 LP HARQ-ACK bits or 1 or 2 HP HARQ-ACK bits). We believe this will bring significant impacts to implementation and specifications.  **Coding performance**: As shown by the simulation results from a number of companies, joint coding can outperform separate coding when the effective coding rate of LP HARQ-ACK is properly controlled (by means of compression/bundling or simply dropping some bits). This is also admitted by some proponents of separate coding.  **Standardization efforts**: As mentioned above, we need to specify repetition coding and simplex coding for PUCCH if only separate coding is supported. For separate coding, we also need to carefully design the resource mapping respectively for HP HARQ-ACK and LP HARQ-ACK to properly adjust the effective coding rates of HP HARQ and LP HARQ, to avoid over-optimization for LP HARQ. Based on these, we don’t think the standardization efforts for separate coding are smaller than joint coding. For joint coding, no new encoder is required and the effective coding rates can be controlled simply by adjusting the number of LP HARQ-ACK bits.  We support the second proposal. |
| DOCOMO | We support the two proposals for the sake of progress. Our original preference was the combination of joint and separate coding according to the some condition, e.g. based on LP payload size. However, it is true that such a condition will make the spec complicated and it is difficult to define a common condition among the proponents for Opt.3. As FL and many companies mention, separate coding outperforms joint coding without compressing/dropping according to the companies’ results. In this regard, we are fine with the two proposals. |
| Nokia/NSB | Support the first proposal.  Support the second proposal. |
| Spreadtrum | Fine with the two proposals. Suggest to remove the second sub-bullet of the first proposal. |
| NEC | We do not support first proposal since we do not think it will have less specification impact as compared to joint coding. Simulation results from other companies have shown that performance of joint coding can be comparable and even better (although with some enhancements) than separate coding in some cases.  We would also like to request clarification about keeping the number of coding chains to 2 for UCI multiplexing on PUCCH if separate coding is used. We think this will not be possible when CSI part I and CSI part II are to be multiplexed with separately encoded LP HARQ-ACK and HP HARQ-ACK.  We are fine with main part of proposal 2. FFS part can be discussed in section 2.6 |
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## 4th round proposals and discussions

The FL suggested companies to provide three inputs in this round:

1. Check the following table of observation, provide questions/challenges to the observations on left, and provide answers/clarifications to the questions/challenges on the right.
2. Show your position on the two options in the 1st proposal (supposing joint + separate coding is excluded.)
3. Show your position on the 2nd proposal

Observation for 4th 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, according to the study and evaluation results,

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|  | Observation for checking | Challenges/Questions to the observation |
| On coding performance | In cases LP HARQ-ACK ≤3bits, joint coding provides same performance as separate coding. | Samsung:  In our simulations for {1 bit HP UCI + 4 bits LP UCI}, separate coding has at least 1 dB gain over joint coding.  If the LP UCI payload is reduced by 1 bit, there will not be a big difference.  Further, that case does not need to be separately discussed – it is similar as 1 bit LP HARQ-ACK. No need for any optimization and no need to complicate specs/implementation.  QC: Like we commented before, 1 bit HP A/N + 2 or 3 bits LP HARQ/ACK is typical use case for URLLC + eMBB on single CC, given typical DL:UL ratio is 4:1/8:2/7:3. Then at least for single CC, which I view as a baseline use case, Rel-15 joint encoding is good enough.  Huawei: To QC: For the TDD 4:1 for example, assuming the HP DL traffic arrives every per slot, the PUCCH on the UL slot is supposed to carry 4 bits HP. If the DL traffic arrives per subslot, even more HP bits will be on the PUCCH. That is why we believe the >2 HP bits case would be more typical in realistic network. |
|  | In other cases (e.g. LP >3bits), Separate coding provides obvious gain on HP HARQ-ACK coding performance over joint coding. Joint coding with enhancements (e.g. LP HARQ-ACK compression, using OCC to embed HP on encoded LP) provided similar or slightly better performance than separate coding. | Lenovo/MotM: Performance of joint coding can be guaranteed by UE multiplexing LP HARQ-ACK only if the payload size of UCI of mixed priorities is not larger than the maximum payload size determined based on the configured *nrofPRBs* and *maxCodeRate.* Thus, we don’t think further enhancement to joint coding for performance is necessary.  QC: Suggest not using subjective wording such as “obvious gain”, “slight better performance” in the observation. Suggest using use objective wording by just capturing how many dBs observed in companies’ simulation results.  Intel: We suggest to revise “LP HARQ-ACK compression” to “LP HARQ-ACK payload reduction”. Compression is one example of it. Partial dropping can be another way.  Sharp: Agree with Intel’s comment using “payload reduction” methods instead.  Quectel: Fine with Intel’s revision, i.e., “payload reduction” instead.  ITRI: share same view with Intel, LP HARQ-ACK could be compressed. |
| On UE implementation complexity | R15 has support 2 coding chains for PUCCH (for CSI part I and II) and 4 coding chains for PUSCH. | QC: Can FL clarify: the 4 coding chains for UCI on PUSCH are for A/N, CSI-1, CSI-2, and PUSCH, right? Then, for the UCIs encoding, Rel-15 only support up to 3 coding chains for UCI on PUSCH.  Intel: Only for PF3/4. For PF2, still joint coding is applied.  Sharp: PUCCH and PUSCH are different, should not compare directly. At least for PUCCH, two coding chains should be enough.  Apple: Two encoding chains should be the maximum with all cases, HP HARQ-ACK, LP HARQ-ACK, and/or SR and/or CSI. |
| Separate coding, joint coding and separate + joint coding would bring similar UE complexity which will not increase over that in R15/R16 NR. | Using the 2 coding chain for different priorities is more complex than using them for same priority.  QC: What we meant about UE complexity is not about “2 coding chain for different priorities is more complex than using them for same priority”. We see separate encoding definitely increases UE complexity substantially. We don’t see how the observation of “similar UE complexity” was drawn. Let me clarify what are the main concern on UE implementation complexity.   1. Besides adding encoders to support separate encoding, our major concern is that UE need to implement the following at least 7 spec changes associated with separate encoding. Please see the 7 spec changes listed in the standard effort section in this table. This increases UE implementation complexity and testing effort significantly. 2. Regarding the # coding chains, with joint encoding, UE can reuse implemented Rel-15 coding chains, except just concatenating HP and LP A/N info bits before feed them into the encoder. Nothing else needs to be done. With separate encoding, it is very likely we will have to implement dedicated coding chains for Rel-17 separate encoding without sharing encoders between Rel-15 and Rel-17 UCI multiplexing. This will increase # encoders not just by 1, but by 2 or 3. One may suggest UE implementation to share encoders between Rel-15 and Rel-17. It is doable theoretically but needs very complicated firmware and software logic to implement the sharing. So we prefer RAN1 spec not forcing UE to take this route. |
| Repetition coding and simplex coding are only supported for 1 or 2 bit UCI on PUSCH in Rel-15/Rel-16. We would have to design and specify these two encoders also for PUCCH if only separate coding is supported (in case of 1 or 2 LP HARQ-ACK bits or 1 or 2 HP HARQ-ACK bits). We believe this will bring significant impacts to implementation and specifications. |
| How to keep the number of coding chains to 2 for UCI multiplexing on PUCCH if CSI part I and CSI part II are to be multiplexed with separately encoded LP HARQ-ACK and HP HARQ-ACK?  QC: We have the same concern as listed in this question: how does it even work?  vivo: This issue can be easily solved by dropping CSI part 2.  Nokia/NSB: The multiplexing of CSI with HP HARQ-ACK and LP-HARQ-ACK hasn’t been discussed/agreed yet. One possibility is to not support such multiplexing, i.e. drop CSI; or at least drop CSI part II, as suggested by vivo.  Huawei: We share the same opinion with vivo and Nokia that R17 HP HARQ-ACK can reuse the R15 HARQ-ACK (and CSI part 1) encoder, and R17 LP HARQ-ACK can reuse the R15 CSI part 2 encoder. The CSI can be dropped for simplicity.  InterDigital: Agree with previous comments that CSI can be dropped.  LG: We also share the same view with other companies that it can be considered to drop CSI.  Ericsson: We have same view as Nokia. We don’t need to support all multiplexing cases. In general, we have to see which multiplexing cases are beneficial in terms of gain and complexity. We don’t think CSI multiplexing with HP HARQ-ACK worth the effort.  Sharp: we don’t think there are more complexity issues if joint coding conditions are defined as special cases, e.g. both HP and LP <=2 bits.  Apple: implementation complexity is always a concern. By leveraging Rel-15 design, we believe a design with either joint encoding or separate encoding is possible with reasonable complexity. Hence it is not enough to just agree on joint encoding or separate encoding in general, or agree on joint encoding or separate encoding for particular cases, HOW that is achieved is very important, and at this time we can have the maximum of encoding chains for all possible UCI multiplexing in Rel-17 won’t exceed that in Rel-15/Rel-16, further RE mapping etc should not change w.r.t. to UCI part I and UCI II. From CSI enhancement, there may be eventually a need to multiplex CSI (e.g. from Case 1 or Case 2 CSI enhancement) with HP HARQ-ACK and LP HARQ-ACK on the same physical channel (PUCCH/PUSCH), but the Rel-15/Rel-16 design can still be leveraged to control the complexity.  QC2: A few questions to Intel/Apple to clarify “Number of encoding chains does not exceed Rel-15 design”. 1) Is the quota of # encoding chains checked per slot or per transmission of PUCCH or PUSCH? 2) when is the check performed, before or after multiplexing?  In my understanding, dropping CSI-2 essentially is a fallback solution to Rel-16. If we go with this route, why not just taking a simpler solution: Always drop CSI (including part 1 and part2) if CSI would multiplex on a PUCCH which has HP A/N. That should automatically guarantee the # encoders not exceeding Rel-15/16. Then it removes the unnecessary effort to define what is the encoder quota check and when to perform the check.  Also, only dropping CSI-2 will lead to HP A/N+ LP CSI-1 joint encoding, while LP A/N is separately encoded with another encoder. If companies don’t want HP A/N+LP A/N joint encoding, why HP A/N + LP CSI-1 joint encoding is fine?  With this, our understanding is that 1) HP A/N reuse the encoder, rate matching equation, and RE mapping rules in Rel-15 for A/N+CSI-1; 2) LP A/N replace the encoder, rate matching equation, and mapping rules in Rel-15 for CSI-2. If this is adopted, then UE implementation complicity can be reduced.  In summary, we could be OK with modified proposal of separate encoding:  Proposal 1: 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 more than 2, Support separate coding for the two HARQ-ACKs, drop CSI (including part 1 and part2, if exist) if CSI would multiplex on a PUCCH which has HP A/N.  Note 1: Strive to let HP A/N reuse the encoder, rate matching equation, and RE mapping rules in Rel-15 for A/N+CSI-1.  Note 2: Strive to let LP A/N reuse the encoder, rate matching equation, and mapping rules in Rel-15 for CSI-2.  Quectel: would both HP CSI-2 and LP CSI-2 be dropped? If yes, why HP CSI-2 has to be dropped due to the multiplexing of LP HARQ-ACK? If no, how to multiplex HP CSI-2 and LP HARQ-ACK, joint coding or separate coding? If separate coding is used, the number of encoding chains would have to be increased. Otherwise, we may have to rule out this kind of multiplexing, i.e., HP CSI and LP HARQ-ACK multiplexing is not supported. |
| Standardization efforts | For joint coding:   * Defining enhancements (e.g. LP HARQ-ACK compression, using OCC to embed HP on encoded LP). | QC: for joint encoding, if we don’t further enhance HP + >=4 bits LP performance, Rel-15 joint encoding has almost zero spec impact. The only spec change is a sentence to describe “concatenate HP A/N and LP A/N info bits before joint encoding them”  Intel: Include partial dropping in the list  Ericsson: As mentioned earlier, if we go for join coding, we prefer simple concatenation and no new schemes of compression, etc.  Sharp: LP HARQ-ACK payload reduction can be conditional depending on the available PUCCH capacity.  Apple: We can also consider joint encoding, concatenation can be used to assemble UCIs, and UCI size reduction may be needed.  Quectel: LP HARQ-ACK payload reduction may be needed also for separate coding when the resource is not enough to accommodate all LP HARQ-ACK bits. |
| For separate coding:   * Signal multiple coding rates for HP and LP HARQ-ACK on PUCCH (also need to signal multiple code rates for HP/LP UCI with different payload size). * New procedures need to be defined to perform separate coding and modulation * PUCCH resource (i.e., #RBs for PUCCH format 2 and 3) determination * RE mapping * Power control | Samsung:  For the first bullet, we don’t agree with the comment in the parentheses - it is  not necessary.  For the remaining bullets, we can simply reuse Rel-16 for separate coding of CSI Part 2 with minimum change.  LG: We share similar view with Samsung that the code rate configured per priority in Rel-16 can be used.  QC: For separate encoding, the following are the list of spec changes needed. I asked the question what the solutions to these open issues are, after one week, I did not get any answer yet. I have to assume they are still completely open. Before understanding what the solutions are to resolve these issues, we cannot accept separate encoding.   * How to signal multiple code rates for HP+LP UCI on PUCCH, HP+LP UCI on PUSCH with UL-SCH? How to signal multiple code rates for HP+LP UCI on PUSCH without UL-SCH? Need double both RRC and DCI signalling overhead? * How to concatenate encoded HP and LP UCI bits? Any interleaving across HP and LP encoded bits to improve robustness to busty error/interference? * How to split/concatenate the HP+LP UCI between the two frequency hops (split between two hops first then concatenate or the other way), when hopping is enabled for HP+LP UCI PUSCH with UL-SCH, PUSCH without UL-SCH. * How to handle the following 4 combinations (puncture + rate match) cases for HP/LP on PUSCH   + <=2 bits HP A/N puncture CSI-2 or PUSCH, <=2 bits LP A/N puncture CSI-2 or PUSCH   + <=2 bits HP A/N puncture CSI-2 or PUSCH, >2 bits LP A/N rate match CSI-2 or PUSCH   + >2 bits HP A/N rate match CSI-2 or PUSCH, <=2 bits LP A/N puncture CSI-2 or PUSCH   + >2 bits HP A/N rate match CSI-2 or PUSCH, >2 bits LP A/N rate match CSI-2 or PUSCH * What is the additional/new rate matching equations for HP+LP UCI on PUCCH, HP+LP UCI on PUSCH with UL-SCH, on PUSCH without UL-SCH * What are the new RE mapping rules to map HP+LP UCI on PUCCH, HP+LP UCI on PUSCH with UL-SCH, or on PUSCH without-UL\_SCH? The new rules start to map HP A/N to which REs, followed by mapping LP A/N to which REs? What are the exact changes needed in the Pseudo codes in Section 6.2.7? * How to decide reference BPRE in power control with separate encoding, when HP+LP UCI transmitted on PUCCH, on PUSCH with UL-SCH, or on PUSCH without UL-SCH?   Sharp: two max code rates are necessary for separate coding, but the Rel-16 configurations may be reused. Also, separate coding is already supported for different CSI parts. |
| For joint + separate coding:   * Besides the above items listed for the two coding schemes, it is needed to define payload threshold/signaling mechanism to switch between the two schemes. | QC: If the switching between separate encoding is based payload threshold, significant amount of simulations (depends on different channel model, Doppler, SNR, etc) are needed for RAN1 to decide the switch threshold.  Intel: We do not support combination. This potentially involves more spec work and performance of the combination scheme may not be significantly better than any of the single coding scheme. We can compromise to single coding approach.  Nokia/NSB: As Intel, we also prefer to support a single coding approach.  NEC: We also prefer single coding approach.  Ericsson: We prefer single coding scheme. Increased complexity for multiplexing LP HARQ-ACK is not justified.  Sharp: Joint coding can be specified for special cases with fixed thresholds and no extra signaling, e.g. if the payload of LP HARQ-ACK is <=2 bits, or bith HO and LP HARQ-ACK are <=2 bits. |

Companies’ position on the two options:

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 more than 2,

* + Option 1: Support separate coding for the two HARQ-ACKs.
  + Support: Samsung, CATT (with FFS of HP HARQ-ACK or LP HARQ-ACK of 1-2 bit(s)), vivo, Intel (second preference, can accept as compromise for progress. Number of encoding chains does not exceed Rel-15 design), ZTE, DCM, Nokia/NSB, Panasonic, Huawei, InterDigital, NEC (2nd preference as a compromise for progress), Sony. LG (with FFS provided by CATT below), Sharp (expect for very small payload, e.g. 2 bits of LP HARQ-ACK), Apple (the number of encoding chains for all UCI multiplexing combinations in Rel-17 should not exceed that in Rel-15/16).
    - CATT: Given that coding of 1 or 2 bit UCI is not support for PUCCH, it needs to be further discussed whether to support separate coding of 1-2 bits.
  + Object: QC
  + Option 2: Support joint coding with enhancement (FFS e.g. LP HARQ-ACK compression, using OCC to embed HP on encoded LP, , partial dropping of LP HARQ-ACK bits) for the two HARQ-ACKs.
  + Support: Lenovo/Motorola Mobility (Support joint coding. FFS any enhancement), QC, Intel (1st preference, added partial dropping in the list of examples), NEC (1st preference), Quectel, ITRI
  + Object: Samsung
    - QC detailed comment: We are also fine with simply use Rel-15 joint encoding. As we commented in above table, Rel-15 joint encoding performance is good enough for single CC scenario, which is the baseline for URLLC+eMBB services. For CA, similar to the 2 bits case, if RAN1 has no appetite to do further enhancement on joint encoding, just introduce minimum enhancement on power control is good enough. So we are also fine to a modified option 2 “Support Rel-15 joint coding ~~with enhancement~~ (FFS any further enhancement e.g. LP HARQ-ACK compression, using OCC to embed HP on encoded LP, power boost) for the two HARQ-ACKs”

Proposal for 4th 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, the baseline is to treat the two bits as HARQ-ACK bits with HP priority and use R15 mapping rules.

* + Support: Lenovo/Motorola Mobility, CATT, vivo, Intel, ZTE, DCM, Nokia/NSB, Panasonic, Huawei, InterDigital, NEC, Sony, LG, Sharp, Quectel, ITRI
  + Ericsson (we are also fine to drop LP HARQ.ACK in this case.
  + Object: Samsung, QC
    - QC detailed comments: Although we proposed some enhancement schemes for this scenario, if RAN1 has no appetite to do enhancement in Rel-17(which we think it is a mistake), for progress, we are OK to take a simple fallback solution. However, fallback to Rel-15 is not acceptable to us, because of the 3dB performance loss to the 1-bit HP. We can either accept fallback to Rel-16 (as Samsung proposed) or fallback to Rel-15 but with power boost for the muxed payload (FFS details on power boost). Please notice by gNB indicating a power boost in power control command for HP bit does not work. The power control command is used to compensate channel variation/fading, if gNB use it to compensate the 3dB loss due to mux with 1 bit LP, then gNB can do nothing with channel variation/fading. Some minimum enhancement in power control is needed if we fallback to Rel-15.

## Multiplexing enable/disable mechanism

## Inputs from Tdocs

* Option 1: DCI indication
  + ZTE (in HP DCI or RRC), vivo, APT, IDC, NEC, Nokia, E///, Quectel, Intel, Pana, Samsung, Sony, ETRI
  + Not support: MTK
* Option 2: RRC configuration
  + HW, Spreadtrum, ZTE (in HP DCI or RRC), vivo, CATT, MTK, IDC (for SPS), China Telecom, CMCC, TCL, Xiaomi, QC, Pana, Samsung, ETRI (if no indication in DCI), LGE, 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 |
| Huawei | ***Proposal 3: Adopt RRC configuration to enable/disable the multiplexing of HP HARQ-ACK and a LP HARQ-ACK on PUCCH, and the multiplexing of HARQ-ACK on PUSCH with different priorities.***   * ***If the RRC parameter indicates ‘Enable’, extra conditions should be specified to check whether the latency/reliability of HP HARQ-ACK can be guaranteed for a certain overlapping case.*** |
| 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.*** |
| ZTE | ***Proposal 4****: The indicator of intra-UE multiplexing UCI with different priorities should be in the scheduling DCI or RRC parameter for the high priority transmission.* |
| vivo | ***Proposal 13: Semi-static indication and dynamic indication of intra-UE multiplexing and prioritization manner can be supported in Rel-17.***  ***Proposal 14: For dynamic indication, multiplexing or prioritization indicator field can be included in DCI with HP or LP or both HP and LP.*** |
| CATT | ***Proposal 10: Semi-static RRC configuration to enable/disable the multiplexing between channels with different priorities is supported.*** |
| MTK | Dynamic indication of the multiplexing activation/de-activation is not supported. |
| APT | Proposal 3 Dynamic indication is supported for indicating whether to multiplex overlapping high priority PUCCH and low priority PUCCH. |
| 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.*** |
| NEC | ***Proposal 4:*** *Support dynamic enabling/disabling of intra-UE HARQ-ACK multiplexing to ensure URLCC performance requirements.* |
| Nokia | * **Proposal 3.1: 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.** * **Proposal 3.4: 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.** |
| E/// | [Proposal 6 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.](#_Toc68676143) |
| China Telecom | **Proposal 1: For multiplexing UCI/PUSCH with different priorities on PUCCH or PUSCH in R17, support RRC configuration to enable/disable the multiplexing as a base line.** |
| Quectel | **Proposal 7**: Dynamic enabling/disabling by DCI for UCI-UCI multiplexing and UCI-PUSCH multiplexing with different priorities is supported on top of RRC configuration. |
| CMCC | Proposal 7: 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. |
| TCL | **Proposal 2: Support explicit indication to enable multiplexing procedure between HP UCI and LP UCI via RRC configuration.** |
| Xiaomi | ***Proposal 10: For enabling/disabling multiplexing of channels of different priorities, semi-static configuration is preferred.*** |
| 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.** |
| Qualcomm | ***Proposal 17:* The Rel-17 intra-UE multiplexing feature is enabled/disabled via RRC configuration on per UE basis.**  ***Proposal 18:* 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.** |
| Panasonic | **Proposal 6:**   * **For multiplexing a HP HARQ-ACK and a LP HARQ-ACK into a PUCCH in Rel.17, the multiplexing is RRC configured.**   + **Dynamic indication for enabling should also be supported.** |
| 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.** |
| Sony | **Proposal 3: The gNB dynamically enables/disable multiplexing in a HP PUCCH by an indication in the DL Grant scheduling the HP PUCCH.** |
| 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.** |
| 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.** |
| Sharp | **Proposal 2: RRC configuration is used as the mechanism to enable/disable the multiplexing of HP HARQ-ACK and a LP HARQ-ACK on PUCCH.** |
| DOCOMO | **Proposal 5:**   * *RRC configuration should be baseline for enabling/disabling multiplexing of LP and HP PUCCH* |

## 1st round proposals and discussions

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, support RRC configuration as a baseline for gNB to enable/disable the multiplexing.

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

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, at least support RRC configuration ~~as a baseline~~ for gNB to enable/disable the multiplexing.

* FFS whether or not to additionally introduce DCI indication to enable/disable the multiplexing
* FFS: Interaction between the enable/disable mechanism and other multiplexing conditions
* FFS for other types of UCI.

Support: QC, CATT, Quetel, DCM, NEC, OPPO, ITRI, ZTE, Sharp, LG, HW, Leno/Moto, Samsung, TCL, Spreadtrum

Not support (DCI should also be supported): Nokia, E///, Intel, IDC, vivo, APT

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| Company | Comments |
| Sony | We still support using DCI indication to enable/disable multiplexing as it offers the most flexibility.  It would be good to clarify what it means by “baseline” here under the context of RRC configuration. RRC configuration would anyhow be required even for DCI indication since the gNB would need to configure the UE with the new DCI indicator. |
| QC | Support FL proposal.  RRC based signaling has to be the baseline because this Rel-17 enhancement has to work for UCI and PUSCH without dynamic DCI, such as A/N for SPS, CG-PUSCH, etc.  Whether DCI based indication is needed can be FFS. Besides the UE complexity and DCI overhead issues, another issue with DCI based indication is how to solve the missing DCI issue? If gNB issue two DCIs, first one indicates multiplexing, second one indicates not multiplexing, if UE missed the second one, mis-alignment is caused between UE and gNB. |
| CATT | We are fine with proposal in general and maybe “as a baseline” can be removed. |
| Quectel | We still prefer to agree DCI indication together with RRC signaling. RRC signaling would be always required. DCI can be used on top of RRC signaling. For no DCI cases (e.g., SPS PDSCH), only RRC signaling is used. By the support of DCI indication, gNB can enable/disable the multiplexing considering different situations with different latency and/or reliability. Otherwise, we may have to specify different conditions (criterion) for multiplexing enabling/disabling considering different situations, which would require huge standardization efforts. |
| DOCOMO | We support the FL proposal in general. In response to Sony’s comment, our understanding on “baseline” is that at least the RRC configuration based semi-statically enabling/disabling will be supported. On top of RRC configuration, we can further discuss whether or not to introduce dynamic enabling/disabling mechanism by DCI. In order to avoid any misunderstanding, we propose the following changes:  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, support RRC configuration ~~as a baseline~~ for gNB to enable/disable the multiplexing.   * FFS whether or not to additionally introduce DCI indication to enable/disable the multiplexing * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI. |
| NEC | Support the FL proposal in general. We also think that the relation between RRC configuration and DCI indication to enable/disable the multiplexing should be clarified, i.e., RRC+DCI, RRC or DCI, DCI indication can override the RRC configuration. |
| Panasonic | We are fine with FL proposal. |
| Nokia/NSB | The proposal is not fully clear to us, and we don’t think it’s really helping to move the discussion forward.  It was already recognized by many companies that RRC configuration is needed anyway. So, the proposal should be more on whether to additionally have the DCI indication. We thus suggest the following updates:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, ~~support~~ in addition to RRC configuration, support DCI indication ~~as a baseline~~ for gNB to enable/disable the multiplexing.   * ~~FFS DCI indication~~ * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI.   In our view, as explained in our Tdoc (R1-2102820), it is 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.  Moreover, supporting dynamic indication for multiplexing would ease the operation and specification effort also in other aspects, such as:   * 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. If the combined payload size would become too large and thereby too much impacting the reliability or latency of the high-priority information, the gNB would simply dynamically disable the multiplexing.   There may be no need to define an extensive set of rules when multiplexing should be possible as this could be left to gNB implementation simplifying the specification effort. |
| OPPO | Support FL proposal.  For DCI indication, it is not applicable for HARQ-ACK feedback for SPS.  For multiplexing condition, it could include payload size and timeline. To be specific,   * If the total UCI bits exceed the capacity of the multiplexing PUCCH resource, low-priority UCI can be compressed until to 0 bit (i.e. low-priority UCI is dropped). * If R15 timeline for multiplexing is satisfied, Multiplexing is applied. Otherwise, fallback to R16 prioritization. |
| Ericsson | Our view is fully aligned with Nokia and we supported the updated proposal by Nokia.  In addition to reasons Nokia mentioned, we would like to raise companies attention to the top-down analysis we provided in our contribution. Depending on the framework (which unfortunately is not clear yet), one can really see that in many cases, the outcome would be without multiplexing. See for example Fig. 5 using B or A-B framework. Such an analysis indicates that there should be a possibility to indicate to UE no need to multiplex. Of course, such indication should be as such that does not increases UE complexity, as pointed out by QC, others. |
| ITRI | We are fine with the proposal. |
| ZTE | Support the FL proposal for progress, but the wording need adjust to “**at least** support RRC configuration” . We can further study the DCI indication. |
| Intel | Support Nokia’s version. DCI indication is needed, e.g., to disable multiplexing when payload control for LP HARQ-ACK may not work given the among of resource. With solely RRS based enable/disable mechanism, lot of more rules need to be defined to achieve the same outcome. |
| Sharp | Support the proposal |
| LG | Support the proposal. |
| InterDigital | Support updated proposal by Nokia. |
| Huawei | Support the proposal.  As explained in our paper, the DCI indication method cannot be applicable to some cases, e.g., the case of HARQ-ACK for PDSCH(s) scheduling by fallback DCI or SPS HARQ-ACKs, or the case of multiplexing LP HARQ-ACK and HP SR. |
| Lenovo, Motorola Mobility | Support the proposal |
| Samsung | Support |
| TCL | Support the proposal |
| vivo | Similar view with Sony and Quectel. DCI indication can offer the most flexibility. It can simplify the multiplexing condition discussion. |
| Spreadtrum | Support the proposal |
| APT | Support updated proposal by Nokia. |

## 2nd round proposals and discussions

Proposal for 2nd round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, at least support RRC configuration for gNB to enable/disable the multiplexing.

* FFS whether or not to additionally introduce DCI indication to enable/disable the multiplexing.
* FFS: Interaction between the enable/disable mechanism and other multiplexing conditions
* FFS for other types of UCI.

|  |  |
| --- | --- |
| Company | Comments |
| Sony | We would prefer that DCI indication to enable/disable multiplexing, i.e.:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, at least support RRC configuration for gNB to enable/disable the multiplexing.   * Introduce DCI indication to enable/disable the multiplexing. * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI. |
| QC | We support FL proposal, based on the rationale we already expressed in 1st round email discussion.  Can proponents of supporting additional DCI indication answer my question raised in first round: If multiple DCIs is associated with multiplexed HP+LP A/N, whether enable/disable multiplexing is based on which DCI? How to solve the issue of missing that DCI, which will cause mis-alignment between gNB and UE? |
| Apple | We support FL ‘s proposal |
| Sharp | Support the proposal. |
| Lenovo, Motorola Mobility | Support |
| DOCOMO | We support the proposal and also are fine with Sony’s update to introduce DCI indication for enabling/disabling. Dynamic indication can be more flexible to guarantee reliability for HP HARQ-ACK. |
| Samsung | Support |
| Quectel | We support Sony’s modification. DCI indication is supported.  If consensus on DCI indication cannot be reached at this meeting. Maybe we can agree that RRC signaling is used for the no DCI case (i.e., the HARQ-ACK for SPS PDSCH) as a small step forward at this meeting. |
| InterDigital | Support Sony’s modification to support DCI indication. |
| vivo | We support Sony’s modification. DCI indication is supported.  gNB can dynamically indicate multiplexing/prioritization based on HARQ-ACK payload/reliability requirement/latency requirement, etc. Otherwise, we need to make extensive discussion on the conditions for multiplexing, such as defining the latency requirement (summarized in 3.6) and/or the reliability requirement.  We think DCI indication is for the PUCCH with corresponding non-fallback DCI, for the case of HARQ-ACK for PDSCH(s) scheduling by fallback DCI or SPS HARQ-ACKs, or other configured PUCCH, it can follow RRC configuration.  For QC’s question, we think it can base on the last DCI (corresponding to the HP HARQ-ACK), the issue of missing DCI is a general issue. To avoid the issue of missing that DCI, same indication can be indicated in multiple DCI.  In addition. one issue may need to be clarified. If RRC configuration for gNB to enable/disable the multiplexing is used. When multiplexing is configured, if the multiplexing conditions (multiplexing timeline) is not met, is it an error case or prioritization is used (if the cancellation timeline defined in Rel-16 is met)? |
| ITRI | Support the proposal. |
| TCL | We support FL’s proposal. |
| Intel | RRC can configure the multiplexing feature, which can be enabled/disabled by DCI indication. So support DCI indication |
| Spreadtrum | Support the proposal. |
| CATT | We support the proposal. |
| Nokia/NSB | Unfortunately, the proposal is still not fully clear to us, and we don’t think it’s really helping to move the discussion forward.  As we previously mentioned, it was already recognized by companies that RRC configuration is needed anyway. So, the proposal should be more on whether to additionally have the DCI indication. We thus suggest the following updates:  For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, ~~at least support~~ in addition to RRC configuration, support DCI indication for gNB to enable/disable the multiplexing.   * ~~FFS whether or not to additionally introduce DCI indication to enable/disable the multiplexing.~~ * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI.   In our view, it is 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. More details are provided in our comment in the first round and in our Tdoc (R1-2102820). |
| MediaTek | Support the proposal. |
| LG | We support the proposal. |
| ZTE | Support Sony/Nokia’s modification to support DCI indication. Either OK with FL proposal to compromise. |
| Huawei | Support. The DCI indication can only be applied for dynamic PUCCH, but does not work for the multiplexing enabling/disabling for semi-static PUCCHs, e.g., SR/SPS HARQ-ACK. In contrast, RRC configuration for enabling/disabling is applicable for both dynamic PUCCH and semi-static PUCCH, thus should be considered as the fundamental way to enable/disable. Regarding the progress, we think it is a constructive way to first agree “at least support RRC configuration”, then to further discuss whether and how to support the DCI indication, instead of agreeing both RRC and DCI at one time. |
| Panasonic | We support the proposal. |

## 3rd round proposals and discussions

Pros and cons of RRC+DCI-based enabling/disabling need to be analyzed. Please input your arguments and answer the questions from the counterpart.

Note: All companies agree to adopt RRC-based enabling/disabling as baseline. So there is no need to discuss the pros and cons of DCI only-based enabling/disabling. Companies can also directly input in the table “Analysis on RRC+DCI-based enabling/disabling”.

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| --- | --- | --- | --- | --- |
|  | | | **Analysis on RRC+DCI-based enabling/disabling** | |
|  | | Arguments | | Counter arguments |
| Advantages | Flexibility | Allow the network to *dynamically* control and avoid any potential impact of multiplexing on the high-priority HARQ-ACK from latency or reliability perspective.  gNB can avoid bad multiplexing scenarios or bad PUCCH resource for multiplexing, as pointed out by QC in Section 2.4.3. | |  |
| Simplify the standardization | Supporting dynamic indication for multiplexing would ease the operation and specification effort also in other aspects, such as:   * 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. If the combined payload size would become too large and thereby too much impacting the reliability or latency of the high-priority information, the gNB would simply dynamically disable the multiplexing.   There may be no need to define an extensive set of rules when multiplexing should be possible as this could be left to gNB implementation simplifying the specification effort. | |  |
| Problems | Missing DCI | If multiple DCIs are associated with multiplexed HP+LP A/N, whether enable/disable multiplexing is based on which DCI? How to solve the issue of missing that DCI, which will cause mis-alignment between gNB and UE?  For example, in case where one LP DCI (e.g. fallback DCI or non-fallback DCI indicating LP) and one HP DCI indicate a same PUCCH slot, and HP SR is configured in the same PUCCH slot, if UE misses the HP DCI, the UE wouldn’t know whether or not to multiplex LP HARQ-ACK and HP SR. For another example, in case where one LP DCI and one HP DCI indicate a same PUCCH slot, and HP HARQ-ACK corresponding to SPS PDSCH is to be in the same PUCCH, if UE misses the HP DCI, the UE wouldn’t know whether or not to multiplex LP HARQ-ACK and HP SPS HARQ-ACK.  Comment to “To avoid the issue of missing that DCI, same indication can be indicated in multiple DCI.”: For URLLC, 1 or 2 bits HARQ-ACK feedback is typical, for urgent but small DL traffic. Then we don’t have multiple DCIs to indicate the same information on enable/disable multiplexing.  Comment to “Missing DCI will also be a problem for RRC only method since UE and gNB will also be out of sync on the number of LP + HP HARQ-ACKs”: the ambiguity is less for RRC based method. With RRC based indication, the codebook size may have ambiguity of +/- 1 or 2 bits, assuming no CGB based Tx here. Hopefully the PUCCH format does not change with this +/- 1 or 2 bits. With DCI based indication, the whole LP codebook can appear or disappear, the dynamic range of the ambiguity of the muxed codebook definitely is larger, which can easier change from PUCCH format 0/1 to PUCCH format 2/3/4. | | It can base on the last DCI (corresponding to the HP HARQ-ACK), the issue of missing DCI is a general issue. To avoid the issue of missing that DCI, same indication can be indicated in multiple DCI.  Missing DCI will also be a problem for RRC only method since UE and gNB will also be out of sync on the number of LP + HP HARQ-ACKs.  In the examples provided by LG, the UE can still determine whether to multiplex or not based on explicit indication (by RRC) associated with the SR or SPS.  The ‘last DCI missed’ scenario can be problematic in some cases (e.g. for single-cell Type-2 codebook) but for most others the NW can control by indicating a same value in a few DCIs. If supported, the feature would be optional, a NW choice for whether or not to deploy, and there is no UE complexity (UE switches between Rel-16 and Rel-17).  In our view, DCI misdetection is not an issue. First, DCI(s) corresponding to HP HARQ-ACK is expected to carry the indication to enable/disable multiplexing, and such DCI(s) is expected to be very reliable. Anyhow, please note that a DCI misdetection, when it occurs, results in misalignment on the HARQ-ACK codebook size when missing a DL assignment (since Rel-15) between the UE and gNB regardless of whether RRC-only or DCI based approach is used. So, we don’t see this as specific for the DCI based solution. |
| Not work in some cases | For SPS HARQ-ACK feedback, RRC+DCI based solution cannot support flexible enabling/disabling. However, in some cases, e.g. timeline is not satisfied or PUCCH resource is not enough to carry both HP UCI and low UCI, flexible enabling/disabling is necessary. So RRC+DCI based solution does not always work. | | The DCI indication can only be applied for dynamic PUCCH, but does not work for the multiplexing enabling/disabling for semi-static PUCCHs, e.g., SR/SPS HARQ-ACK, thus it is not a unified solution to solve the enabling/disabling for all cases. |
| Necessity over mux condition | If multiplexing condition is required to ensure necessary enabling/disabling switch, then what else use case requires RRC+DCI based solution? | |  |

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| Company | Comments |
| Sony | Greater gNB scheduling flexibility and also gNB can avoid bad multiplexing scenarios or bad PUCCH resource for multiplexing, as pointed out by QC in Section 2.4.3.  The enabling/disabling should always follow the last DCI since this allows the gNB to adapt its scheduling as it schedules PDSCH. Even for PUCCH scheduling, the UE follows the PRI from the last DCI, so a similar approach should be taken.  Missing DCI will also be a problem for RRC only method since UE and gNB will also be out of sync on the number of LP + HP HARQ-ACKs. |
| OPPO | For SPS HARQ-ACK feedback, RRC+DCI based solution cannot support flexible enabling/disabling. However, in some cases, e.g. timeline is not satisfied or PUCCH resource is not enough to carry both HP UCI and low UCI, flexible enabling/disabling is necessary. So RRC+DCI based solution does not always work.  If multiplexing condition is required to ensure necessary enabling/disabling switch, then what else use case requires RRC+DCI based solution? |
| LG | Regarding the above problem and counter argument with RRC+DCI-based enabling/disabling (in the above table), I’d like to provide some example which may be able to explain the issue with DCI-based enabling/disabling.  For example, in case where one LP DCI (e.g. fallback DCI or non-fallback DCI indicating LP) and one HP DCI indicate a same PUCCH slot, and HP SR is configured in the same PUCCH slot, if UE misses the HP DCI, the UE wouldn’t know whether or not to multiplex LP HARQ-ACK and HP SR. For another example, in case where one LP DCI and one HP DCI indicate a same PUCCH slot, and HP HARQ-ACK corresponding to SPS PDSCH is to be in the same PUCCH, if UE misses the HP DCI, the UE wouldn’t know whether or not to multiplex LP HARQ-ACK and HP SPS HARQ-ACK.  Note that similar situation could occur in case with DCI-based enabling/disabling for UCI multiplexing on PUSCH. |
| Huawei | As mentioned in the 2nd round, The DCI indication can only be applied for dynamic PUCCH, but does not work for the multiplexing enabling/disabling for semi-static PUCCHs, e.g., SR/SPS HARQ-ACK, thus it is not a unified solution to solve the enabling/disabling for all cases. Similarly, DCI indication does not work for the multiplexing enabling/disabling for semi-static PUCCHs/PUSCHs, e.g., SR/SPS HARQ-ACK/CG PUSCH. |
| InterDigital | Explicit indication (e.g. by field in a HP DCI) enables more robust operation for the HP traffic which is the most important.  In the examples provided by LG, the UE can still determine whether to multiplex or not based on explicit indication (by RRC) associated with the SR or SPS. |
| Samsung | The ‘last DCI missed’ scenario can be problematic in some cases (e.g. for single-cell Type-2 codebook) but for most others the NW can control by indicating a same value in a few DCIs. If supported, the feature would be optional, a NW choice for whether or not to deploy, and there is no UE complexity (UE switches between Rel-16 and Rel-17). |
| ZTE | For the special case which DCI is not applicable, UE could follow the RRC configuration. It is acceptable that DCI indication to be used for most cases. |
| QC | Comment to “To avoid the issue of missing that DCI, same indication can be indicated in multiple DCI.”: For URLLC, 1 or 2 bits HARQ-ACK feedback is typical, for urgent but small DL traffic. Then we don’t have multiple DCIs to indicate the same information on enable/disable multiplexing.  Comment to “Missing DCI will also be a problem for RRC only method since UE and gNB will also be out of sync on the number of LP + HP HARQ-ACKs”: the ambiguity is less for RRC based method. With RRC based indication, the codebook size may have ambiguity of +/- 1 or 2 bits, assuming no CGB based Tx here. Hopefully the PUCCH format does not change with this +/- 1 or 2 bits. With DCI based indication, the whole LP codebook can appear or disappear, the dynamic range of the ambiguity of the muxed codebook definitely is larger, which can easier change from PUCCH format 0/1 to PUCCH format 2/3/4. |
| Quectel | For the same reasons mentioned by some companies above, we support DCI indication. |
| DOCOMO | UE should follow the last DCI for whether the multiplexing is enabled/disabled since it let gNB dynamically change the multiplexing behavior on its preference based on scheduling condition even after sending the first DCI. |
| Nokia/NSB | In our view, DCI misdetection is not an issue. First, DCI(s) corresponding to HP HARQ-ACK is expected to carry the indication to enable/disable multiplexing, and such DCI(s) is expected to be very reliable. Anyhow, please note that a DCI misdetection, when it occurs, results in misalignment on the HARQ-ACK codebook size when missing a DL assignment (since Rel-15) between the UE and gNB regardless of whether RRC-only or DCI based approach is used. So, we don’t see this as specific for the DCI based solution.  Reiterating our view on why we think DCI-based solution should be adopted:  As explained in our Tdoc (R1-2102820), it is 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.  Moreover, supporting dynamic indication for multiplexing would ease the operation and specification effort also in other aspects, such as:   * 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. If the combined payload size would become too large and thereby too much impacting the reliability or latency of the high-priority information, the gNB would simply dynamically disable the multiplexing.   There may be no need to define an extensive set of rules when multiplexing should be possible as this could be left to gNB implementation simplifying the specification effort. |
| Spreadtrum | As mentioned by some above companies, DCI missing issue can be handled by NW in most of cases. For some especially urgent and important use cases, RRC+DCI-based enabling/disabling can be considered. |
| NEC | DCI based enabling/disabling on top of RRC configuration can ensure that any detrimental effect on HP HARQ-ACK reliability or latency is avoided. |
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## PUCCH resource determination and mapping for multiplexing between HARQ-ACKs with different priorities

## Inputs from Tdocs

**In case the total number of LP and HP HARQ-ACK bits is 2:**

* Option 1: Select the PUCCH resource from the second *PUCCH-Config*.
  + HW, Spreadtrum, ZTE, CATT, Nokia, China Telecom, Xiaomi, Sharp, DCM

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|  | | Arguments | Counter arguments |
| Option 1 | Advantages | It can be guaranteed that the selected PUCCH resource uses the same power control as well as spatial processing as the PUCCH resource carrying the HP HARQ-ACK, and hence ensures the reliability of the HP transmission.  Unified solution with HARQ-ACK bits >2. |  |

**Reuse PUCCH resource in the second *PUCCH-Config* configured for HP HARQ-ACK vs. Configure a dedicated PUCCH resource for HP+LP**

* Option 1: Reuse PUCCH resource in the second *PUCCH-Config* configured for HP HARQ-ACK
  + Spreadtrum, ZTE, IDC, Xiaomi, Sharp, DCM
* Option 2: Configure a dedicated PUCCH resource for HP+LP
  + HW, Quectel, Pana, ETRI

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| --- | --- | --- | --- |
| Resource determination for multiplexing between HARQ-ACKs with different priorities | | | |
|  | | Arguments | Counter arguments |
| Option 1a | Advantages |  |  |
| Option 2 | Advantages | Avoid the decoding error of HP HARQ-ACK due to the ambiguity of the LP HARQ-ACK number. The gNB can configure different PUCCH resources (RB/CS/OCC) for HP only and hybrid HP+LP, respectively, and simply perform the blind detection of PUCCH DMRS on the two hypotheses for easy verification of the LP DCI missing. | The ambiguity due to the uncertainty of LP HARQ-ACK multiplexing with HP HARQ-ACK can be solved by gNB implementation, i.e. blind decoding the PUCCH based on the hypothesis of different payload size under the condition that whether the LP HARQ-ACK is multiplexed with HP HARQ-ACK or not. |
| Problems | Considering that maximum 16 resources can be configured in each PUCCH-resource-set, and the reliability of scheduling DCI for HP HARQ-ACK is generally high enough to avoid miss detection, we do not see much necessity to configure dedicated PUCCH resources for multiplexing. |  |

**Resource mapping rules:**

* + If no enough resource for both HP and LP HARQ-ACK.
    - Option 1: LP HARQ-ACK is compressed/bundled/Compaction.
      * OPPO, ZTE, MTK, TCL, LGE (bundling for LP HARQ-ACK in spatial domain and/or CBG domain), WILUS
    - Option 2: LP HARQ-ACK is dropped.
      * LGE,
    - Option 3: LP HARQ-ACK is partially dropped.
      * TCL, Intel

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| --- | --- |
| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 4: Support a group of dedicated PUCCH sets in the second PUCCH-Configuration to carry the multiplexed HP HARQ-ACK and LP HARQ-ACK.*** |
| OPPO | ***Proposal 3: A PUCCH resource in the PUCCH resource set configured for HP HARQ-ACK is used to transmit HP HARQ-ACK and LP HARQ-ACK.***  ***Proposal 4: The PUCCH resource for multiplexing HP HARQ-ACK and LP HARQ-ACK is determined based on the PRI indicated in the last HP DCI and an offset.***   * ***If the value of C-DAI in the last LP DCI is even or no LP DCI is received, ;*** * ***Otherwise, .*** |
| Spreadtrum | 1. ***Not support to configure dedicate PUCCH resources for multiplexing of HP HARQ-ACK and LP HARQ-ACK.*** 2. ***Support to multiplex on the HP PUCCH resources if a 1 bit LP HARQ-ACK overlaps with a 1 bit HP HARQ-ACK*** |
| ZTE | ***Proposal 5****: For the case that the total number of bits is no more than 2 bits, the PRI+x in the HP DCI is used to implicitly determine an extended PUCCH resource from the PUCCH set in the PUCCH-config with high priority for the multiplexed UCI,, x is predefined, e.g., x=1.*  ***Proposal 11:*** *LP UCI compression is slightly preferred in case there is no enough resource left for LP UCI.* |
| 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 treated as two HP HARQ-ACK bits and transmitted on the time-frequency resource for the HP HARQ-ACK transmission.*** |
| MTK | Group-bundling is supported when multiplexing and when the resulted UCI payload is large. |
| 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.** |
| 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 (for any total number of LP and HP bits).***  ***Proposal 10: DCI indicating HP HARQ-ACK includes an indication of the DAI of LP HARQ-ACK.*** |
| Nokia | * **Proposal 3.3: For the scenario where a PUCCH carrying 1-bit high-priority HARQ-ACK overlaps with another PUCCH carrying 1-bit low-priority HARQ-ACK, the multiplexing of high-priority HARQ-ACK and low-priority HARQ-ACK is done on the high-priority PUCCH resource.** * ***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 3.5: 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.** * **Proposal 3.6: 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. The order of the two bits could be [high-priority HARQ-ACK bit, low-priority HARQ-ACK bit].** |
| China Telecom | **Proposal 3: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH when the total number of bits is 2,**   * **Treat the two bits as HARQ-ACK bits with HP and using R15 mapping rules.** * **Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK).** |
| Quectel | **Proposal 2**: Optional configuration of a set or subset of PUCCH resources dedicated for multiplexing of UCIs with different priorities is supported.  **Proposal 3**: For separate coding, the sum number of HP HARQ-ACK bits and LP HARQ-ACK bits is used to determine the HP PUCCH resource set for HP HARQ-ACK and LP HARQ-ACK multiplexing; for joint coding, the sum number of HP HARQ-ACK bits and LP information bits derived by bundling or compressing (if adopted) is used to determine the HP PUCCH resource set for HP HARQ-ACK and LP HARQ-ACK multiplexing .  **Proposal 4**: When HP DCI corresponding to the HP HARQ-ACK is available, the PRI contained in HP DCI is used to determine the target HP PUCCH resource from the HP PUCCH resource set; when HP DCI corresponding to the HP HARQ-ACK is unavailable (i.e., SPS PDSCH), the number of information bits is used to determine the HP PUCCH resource based on existing rules for SPS PDSCH. |
| TCL | **Proposal 1: 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.** |
| Xiaomi | ***Proposal 5: Configuring dedicated resources for multiplexing of HP HARQ-ACK and LP HARQ-ACK is not necessary.***  ***Proposal 6: When the total number of LP and HP HARQ-ACK bits is 2, PUCCH resource of the HP HARQ-ACK should be adopted as the resource for multiplexing.*** |
| Apple | **Proposal 3-1: For {HP HARQ-ACK at PUCCH Format 0, LP HARQ at PUCCH Format 0}, or {HP HARQ-ACK at PUCCH Format 1, LP HARQ at PUCCH Format 1}, or {HP HARQ at PUCCH Format 1, LP HARQ at PUCCH Format 0},**   * **If there are HP HARQ-ACK bit(s), LP HARQ-ACK bit(s), then is used to look up a HP PUCCH resource set/HP PUCCH resource.**    + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, 3 bits are counted in the payload.** * **If there are 1 HP HARQ-ACK bit, 1 LP HARQ bit (i.e. , then 1 padding bit included with them, bits is used to look up a HP PUCCH resource set/HP PUCCH resource.**   + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, then 3 bits are counted in the payload (1 HP HARQ-ACK bit + 1 LP HARQ bit + 1 padding bit).**   **Proposal 4-1: For {HP SR at PUCCH Format 0, LP HARQ-ACK at PUCCH Format 0}, or {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 1}, or {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 0}, {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 0},**   * **If there are 2 HARQ-ACK bits, then the 1 SR bit is included in the payload, bits is used to look up a HP PUCCH resource.**    + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, 3 bits are counted in the payload.** * **If there are 1 HARQ-ACK bit, 1 SR bit, then 1 padding bit included with them, bits is used to look up a HP PUCCH resource.**   + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, then 3 bits are counted in the payload (1 HARQ-ACK bit + 1 SR bit + 1 padding bit).**   **Proposal 5-1: leverage the Rel-15 design, LP HARQ-ACK can be mapped to UCI Part II in separate encoding.**  **Proposal 5-2: leverage the Rel-15 design, LP HARQ-ACK can be mapped to UCI Part I in joint encoding.**  **Proposal 5-3: HP and LP CSI is jointly treated for CSI omission, introduce physical layer priority in the CSI priority rule.**  **Proposal 6-1: leverage the Rel-15/16 design, LP HARQ-ACK can be mapped to UCI Part I or UCI part II in separate encoding.**  **Proposal 6-2: leverage the Rel-15/16 design, LP HARQ-ACK can be mapped to UCI Part 0 in joint encoding.**  **Proposal 8-1: consider PRB # adjustment and CSI omission/HARQ compaction for the PUCCH resource under multi-CSI-PUCCH-ResourceList and pucch-CSI-ResourceList.** |
| Panasonic | **Proposal 7: In case the total number of LP and HP HARQ-ACK bits is more than 2, PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.** |
| ETRI | **Proposal 4: Whenever being transmitted, all the LP HARQ-ACK bits are multiplexed.**  **Proposal 5: Introduce additional PUCCH resource set for multiplexing HP UCI and LP UCI when more than two bits in total are involved.**  **Proposal 6: The LP DCI determines the final PUCCH resource in at least for the HP SPS case.**  **Observation 1: The proposed options may reduce the multiplexing capability in the PUCCH resource set from the second PUCCH config.**  **Proposal 8: Introduce additional PUCCH resource set for multiplexing HP UCI and LP UCI when two bits in total are involved.** |
| LGE | **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.**  **Proposal #8: Discuss and decide at least the following details for PUCCH resource determination based on the agreed HP PUCCH configuration.**   * **How to select one of multiple HP PUCCH resource sets** * **How to determine a PUCCH resource in the selected HP PUCCH resource set** |
| Sharp | **Proposal 4: A HP PUCCH resource configured for HP HARQ-ACK should be used for HP HARQ-ACK and LP HARQ-ACK multiplexing on PUCCH for all case.** |
| DOCOMO | **Proposal 4:**   * *PUCCH resource for HP HARQ-ACK is used for multiplexing LP HARQ-ACK and HP HARQ-ACK.* |
| Leno/Moto | * **Proposal 1:** A PUCCH resource configured by the second *PUCCH-Config*for multiplexing UCI of mixed priorities including up to 2bit HARQ-ACK information with/without a positive HP SR is determined based on:   + a last DCI format indicating a higher priority index, or   + a last DCI format if no DCI format indicating a higher priority index is detected, or   + a PUCCH resource configured for UCI of mixed priorities for up to 2 HARQ-ACK bits with a positive SR, when there is no corresponding DCI format. * **Proposal 2:** UE determines whether to multiplex LP HARQ-ACK with HP UCI in a PUCCH resource of PUCCH format 2, 3, or 4 of higher priority index, based on the total UCI payload size and configured max. code rate/max PRB parameters. |
| WILUS | * ***Proposal 4: Further discuss whether/how to multiplex HP HARQ-ACK and LP HARQ-ACK in a PUCCH resource if the second PUCCH-Config contains only the first PUCCH resource (for 1- or 2-bit HARQ-ACK information).*** * ***Proposal 5: If the required # of RBs for low-priority HARQ-ACK information exceed the limit of PUCCH formats, then bundle the low-priority HARQ-ACK information. Detail bundling rules should be further discussed in Rel-17 URLLC/IIoT WI.*** |

## 1st round proposals and discussions

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,

* Use a PUCCH resource in the second *PUCCH-Config* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) in case the total number of LP and HP HARQ-ACK bits is 2.

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* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) in case the total number of LP and HP HARQ-ACK bits is 2.
* FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.
* FFS: the case where HARQ-ACK is for SPS

Support: Sony, CATT, Quectel, DCM, NEC, Pana, Nokia, OPPO, E///, ITRI, ZTE, Intel, Sharp, LG, IDC, Apple, Leno/Moto, Samsung, TCL, Spreadtrum, APT

Not support: QC (first decide on Section 2.6)

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| Company | Comments |
| Sony | Agree |
| QC | In Section 2.6, there are many companies propose to do resource selection, for example, when the overlapping HP SR and LP HARQ-ACK are both in PF1, this FL proposal conflicting with those resource selection proposals. We suggest to settle down proposals in Section 2.6 first, before discussion this proposal. Our view is that, after the issues in section 2.6 are settled, the resource selection for total bits =2 will be automatically resolved. At this point, we cannot accept this proposal. |
| CATT | Agree |
| Quectel | Support |
| DOCOMO | Support |
| NEC | Agree |
| Panasonic | We are fine with the FL proposal. |
| Nokia/NSB | Support the proposal. |
| OPPO | Support FL proposal |
| Ericsson | Support the proposal. However, we see this proposal is **equivalent to 2nd Proposal in section 2.2.2.** |
| ITRI | Support the proposal |
| ZTE | Agree |
| Intel | Support |
| Sharp | Suppport |
| LG | Support |
| InterDigital | Support |
| Apple | Support |
| Huawei | We can support if the following FFS is added on top of the main bullet to align with the agreement for the >2 bits case.  “  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) in case the total number of LP and HP HARQ-ACK bits is 2. * FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.   ”  Note that it would be a simple and flexible way for the gNB to configure a dedicated HARQ-ACK resource for HP+LP per PUCCH set per PRI to resolve the bit number ambiguity issue due to missing LP DCI. As shown in the following figure, the HP only HARQ-ACK on the blue resource while the HP+LP HARQ-ACK on the green resource. The gNB can perform blind detection of PUCCH DMRS to identify the actually transmitted PUCCH.  As a clarification for the Counter arguments of Option 2: the complexity of gNB to blind detect sequences/DMRS signals of different candidate PUCCHs is relatively low. But the gNB blind decoding the encoded signals with two or more hypothesis is quite high, as the parallel decoders need to be designed. This is one reason why DAI is introduced for the type 2 HARQ codebook to align the understanding of HARQ-ACK bit number between gNB and UE, since otherwise the gNB has to blind decode to determine the exact bit number. |
| Lenovo, Motorola Mobility | Support the proposal |
| Samsung | Support |
| TCL | Support |
| vivo | For the case of HARQ-ACK is for SPS, and UE is not configured with *SPS-PUCCH-AN-List* in each *PUCCH-config*. For example, UE is only configured one SPS with low priority and one SPS with high priority. The HP HARQ-ACK PUCCH is provided by *n1PUCCH-AN,* which is not necessarily configured in the second *PUCCH-config*. |
| Spreadtrum | Support |
| APT | Support |

## 2nd round proposals and discussions

Proposal for 2nd 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* (the *PUCCH-config* containing the PUCCH resource of the HP HARQ-ACK) in case the total number of LP and HP HARQ-ACK bits is 2.
* FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.
* FFS: the case where HARQ-ACK is for SPS

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| Company | Comments |
| Sony | Support. |
| QC | We don’t support this proposal, because 1) the proposal does not work in some cases; 2) the proposal clearly is not a good design in most of the cases.  In our view, there are 4 cases for 2 bits scenario:  Case 1: 1-bit HP in PF0 overlap with 1-bit LP in PF0. In this case, 1 bit HP PUCCH resource only has 2 CS indices. It clearly cannot transmit muxed 2 bits. So the proposal does not work in this case. We need discuss how to extend HP resource from 2 CS to 4 CS.  Case 2: 1-bit HP in PF0 overlap with 1-bit LP in PF1. Following the proposal, 2 bits muxed payload will be transmitted in PF0. Based on same reason for case 1, the proposal does not work. Furthermore, there is a much better yet very simple solution for this case, which is TDM HP and LP as illustrated below. By TDM, HP performance is (at least) same as Rel-16, no performance loss after multiplexing. LP is still transmitted. If we want to further boost HP performance, we can give more OFDM symbols to HP. And there is no spec impact or implementation impact, as the TDM of a short and long PUCCH is already supported in Rel-15. So the TMD solution is also Rel-15 baseline.    Case 3: 1-bit HP in PF1 overlap with 1-bit LP in PF0. Following the proposal, 2 bits muxed payload will be transmitted in PF1 follow Rel-15. But the energy split is half-half between HP and LP, which apparently is not good. Again, a much better yet simple solution is the TDM solution, as illustrated below.    Case 4: 1 bit HP in PF1 overlap with 1-bit LP in PF1. Following the proposal, 2 bits muxed payload will be transmitted in PF1 follow Rel-15. But the energy split is half-half between HP and LP, which apparently is not good. Again, a much better yet simple solution is the TDM solution, as illustrated below. |
| Apple | Support |
| Sharp | Support |
| Lenovo, Motorola Mobility | In principle, we support the proposal. The suggested modification/clarification shown below  ------------  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) in case the total number of LP and HP HARQ-ACK bits is 2.   + FFS: How to determine a PUCCH resource in the second *PUCCH-Config*     - FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.     - FFS: the case where HARQ-ACK is for SPS |
| DOCOMO | Support |
| Samsung | Support in principle. We think the 2 FFS should be removed because of the following agreement from RAN1#104-e that does not exclude SPS. The 2nd FFS re-opens the discussion for what was agreed for more than 2 bits. If making a new agreement with the 2 FFS does not preempt the following agreement from RAN1#104-e, OK to proceed and not spend time discussing the FFS.    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* |
| Quectel | Support the proposal  We think the problems raised by QC could be largely alleviated by implementation (e.g., power boosting for HP PUCCH by an independent parameter setting or just simply disable the multiplexing by DCI indication if the potential performance degradation for HP is not acceptable) . We prefer a simple solution. |
| InterDigital | Support the proposal.  Also, not sure I understand the relevance of examples shown by Qualcomm. The network knows that multiplexing will take place and controls the resource for multiplexing. Why would it select a resource for which multiplexing cannot work? |
| vivo | Support in principle |
| ITRI | Support the proposal. |
| TCL | Support the proposal. |
| Intel | Support |
| Spreadtrum | Support the proposal. |
| CATT | We support the proposal in general and would like to propose the following update to the second FFS to make it clearer.  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) in case the total number of LP and HP HARQ-ACK bits is 2. * FFS: The PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK.   FFS: the case where HARQ-ACK is for SPS and only one PUCCH resource is configured for HP SPS HARQ-ACK |
| Nokia/NSB | Support the proposal in principle.  We are not really clear about the need for the first added FFS, but we will not object it if some companies prefer to have it there. |
| MediaTek | Support the proposal. |
| LG | We support the proposal in principle.  Moreover, on this PUCCH resource determination, we suggest the following two FFS points which are more fundamental than other aspects.   * FFS: How to select one of multiple HP PUCCH resource sets (e.g. based on the total payload size of LP UCI and HP UCI, or based on the payload size of HP UCI only) * FFS: How to determine a PUCCH resource in the selected HP PUCCH resource set (e.g. based on the PRI in the last DCI indicating HP, or based on the PRI in the last DCI) |
| ZTE | Support the proposal. |
| Huawei | Support |
| Panasonic | We support the proposal. |

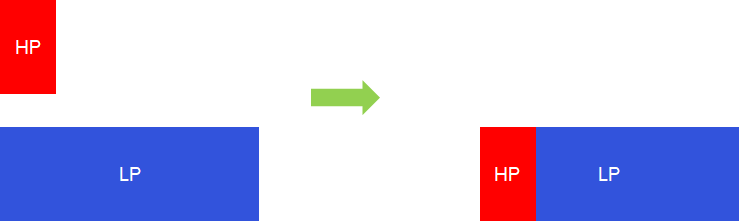
## 3rd round proposals and discussions

After the 2nd round discussion, most of companies support the proposal. For Qualcomm’s questions, companies are encouraged to provide answers/analysis.

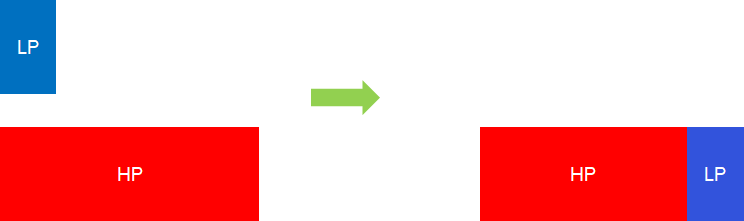
Qualcomm thinks the proposal does not work in some cases. And the proposal clearly is not a good design in most of the cases. In their view, there are 4 cases for 2 bits scenario:

Case 1: 1-bit HP in PF0 overlap with 1-bit LP in PF0. In this case, 1 bit HP PUCCH resource only has 2 CS indices. It clearly cannot transmit muxed 2 bits. So the proposal does not work in this case. We need discuss how to extend HP resource from 2 CS to 4 CS.

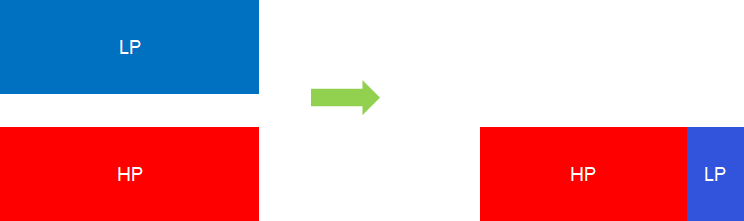
Case 2: 1-bit HP in PF0 overlap with 1-bit LP in PF1. Following the proposal, 2 bits muxed payload will be transmitted in PF0. Based on same reason for case 1, the proposal does not work. Furthermore, there is a much better yet very simple solution for this case, which is TDM HP and LP as illustrated below. By TDM, HP performance is (at least) same as Rel-16, no performance loss after multiplexing. LP is still transmitted. If we want to further boost HP performance, we can give more OFDM symbols to HP. And there is no spec impact or implementation impact, as the TDM of a short and long PUCCH is already supported in Rel-15. So the TMD solution is also Rel-15 baseline.



Case 3: 1-bit HP in PF1 overlap with 1-bit LP in PF0. Following the proposal, 2 bits muxed payload will be transmitted in PF1 follow Rel-15. But the energy split is half-half between HP and LP, which apparently is not good. Again, a much better yet simple solution is the TDM solution, as illustrated below.



Case 4: 1 bit HP in PF1 overlap with 1-bit LP in PF1. Following the proposal, 2 bits muxed payload will be transmitted in PF1 follow Rel-15. But the energy split is half-half between HP and LP, which apparently is not good. Again, a much better yet simple solution is the TDM solution, as illustrated below.



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| Company | Comments |
| Sony | As pointed out by others, the issues raised by QC can be solved by using DCI indicator to enable/disable multiplexing. If the PUCCH resource is poor then gNB can dynamically disable multiplexing or indicate an appropriate PUCCH resource, e.g. using the PRI.  Also, PF0 can carry up to 2 HARQ-ACKs and 1 SR. If the gNB uses DCI to enable multiplexing, it would use also indicates the appropriate PRI so that the LP HARQ-ACK and HP HARQ-ACK can be multiplexed.  This issue raised also shows the benefit of using DCI indicator to enable/disable multiplexing. |
| LG | Basically, we don’t see any critical issue for the above Case 1 and 2, and we see some problem with the scheme proposed for Case 3 and 4.  Firstly, related to Case 1 and 2, our understanding is that currently, PF0 resource is not allocated for a fixed number of HARQ-ACK bits (e.g. only for 1 bit). Rather, the number of CSs used in the allocated PF0 resource would be varied according to the number of HARQ-ACK bits to be transmitted (from 1 to 2). So, in case when LP+HP multiplexing is enabled, since total number of HARQ-ACK bits would be 2, 4 CSs are used in HP PF0 resource.  Secondly, regarding Case 3 and 4, if we go with TDM approach as in above where the last 1or 2 symbol(s) in HP PF1 resource is punctured in order to shift LP PF0 resource (if understood correctly), time-domain OCC applied to HP PF1 would be broken, and then performance loss would be inevitable. Moreover, considering 2-bit HP HARQ-ACK only case, the energy split is being happen in the same way (e.g. half-half between first HP bit and second HP bit). |
| Huawei | Firstly at R15, the 2 bits HARQ-ACK payload can be carried by both PUCCH format 0 (4 CSs) and PUCCH format 1 (QPSK). Regarding the demodulation/decorrelation performance may be harmed due to the multiplexing of HP and LP as mention in our paper [R1-2102353], a dedicated resource can be configured for HP+LP for distinguishing.  If the power compensation is the concern, the TPC for PUCCH can be applied to compensate the power after multiplexing. |
| InterDigital | Still don’t understand the relevance of these cases. It is the same gNB that schedules the HP and LP transmission and it controls whether the overlap occurs or not. Why would it indicate a resource over which multiplexing does not work? |
| Apple | Our understanding is **a** PUCCH resource from a HP PUCCH resource set is selected, the selected PUCCH resource is not necessarily the colliding HP PUCCH resource; so the problem mentioned by QC can be avoided.  In our view, a simple solution is to just treat the payload as 3 bits with padding, so all the issues with PF0/PF1 are gone. |
| Panasonic | We think the issue on PUCCH resource can be solved when PUCCH resource is configured dedicated for multiplexing of HP HARQ-ACK and LP HARQ-ACK. |
| Samsung | No need to support – Rel-16 is sufficient - there is no impact on system throughput.  As we mentioned in previous comments, these are very low probability cases (probability is smaller than HARQ-ACK BLER). |
| ZTE | CASE 1: extending 2CS to 4CS has already specified.  CASE 2: same answer as CASE 1, TDM manner may be possible, but punching my degrade the performance and need more specification effort.  CASE 3: Energy problem could be solved by power boosting.  CASE 4: same answer as CASE 3. |
| QC | To Sony: yes, if dynamic DCI indication is used, it can solve this 3dB performance degradation problem. But dynamic indication has its own problem of missing DCI and it increased UE implementation complexity, because it requires UE to dynamically switch between two modes.  To LG: for all the cases, do we agree by mux 1-bit LP on the HP resource, the HP performance degrade by 3dB? Spec already doing this for 1 bit HP + 1-bit HP does not justify we have to do it that way all other cases. If following this principle, then I say we don’t need to discuss separate vs joint encoding for HP + LP >2 bits, spec already did joint encoding for HP + HP >2 bits.  To HW: The use case of TPC command is to compensate for channel fading/variation in time. If we use TPC to dedicatedly compensate the 3dB power loss, then it cannot be used to compensate channel fading/variation. So, if we reuse Rel-15, at least, some enhancement on power control is needed for the muxed 2 bits.  To InterDigital: typically, 1 bit HP A/N is scheduled because of urgent DL traffic. Then gNB cannot avoid to schedule the urgent HP A/N on a resource that mux may not work, because gNB cannot afford to further delay the HP A/N. |
| Quectel | For the same comments as majority companies and as we commented in the 2nd round, we don’t think this is a big problem. |
| DOCOMO | Share the same view as Apple. In our understanding, the proposal says that a PUCCH resource is selected from a HP PUCCH resource set and the selected PUCCH resource may or may not same as the original HP PUCCH resource. Therefore, the problem raised by Qualcomm can be avoided by selecting appropriate HP PUCCH resource. Even if there is no appropriate one, gNB could disable the multiplexing by DCI indication (, if supported). |
| Nokia/NSB | We don’t really see the issue(s). By treating the two bits as HP bits, we can reuse the existing mapping schemes (of two HP bits) on PF0/PF1; e.g. the order can be [HP HARQ-ACK bit, LP HARQ-ACK bit], i.e. the high-priority HARQ-ACK defines the 1st or MSB of the two bits. And the same performance as for the scenario where two HP HARQ-ACK bits are transmitted on F0/PF1 is achieved. Besides, gNB implementation/configuration would have several tools to avoid any unwanted impact on the HP bit if needed. |
| NEC | The problem can be avoided by selecting appropriate PUCCH resource from the HP resource set. If gNB determines that an appropriate resource may not be selected, it can disable multiplexing. |
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## 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, China Telecom, TCL
  + Option 1b: X>0.
    - CMCC

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| Company | Proposals/observations from Tdocs |
| 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.***  ***Proposal 6: For Rel-17 intra-UE PUCCH/PUSCH multiplexing, confirm the working assumption to reuse intra-UE PUCCH/PUSCH multiplexing timeline requirements and if the timeline requirements are not satisfied, return back to Rel-16 prioritization rule.*** |
| CATT | ***Observation 1: Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities will introduce more limitation on scheduling for high priority channels in Rel-17.***  ***Observation 2: If the timeline requirement is allowed to be not met, gNB and UE may have different understandings on whether the multiplexing timeline is satisfied and whether the multiplexing should be performed.***  ***Proposal 2: The time unit of high priority PUCCH is used as the time unit for multiplexing.***  ***Proposal 3: For a low priority PUCCH which goes across multiple time units for multiplexing, the low priority PUCCH joins the multiplexing procedure in each of the overlapping time units for multiplexing from the first overlapping slot, unless the low priority PUCCH was determined to be dropped or multiplexed with other channels.*** |
| MTK | 1. Guard gap timeline of the new multiplexed PUCCH is of the earliest PUCCH. 2. Multiplexing allowed only if the resulted PUCCH is confined within the sub-slot of the HP-PUCCH sub-slot. |
| Nokia | * **Proposal 3.14: For the scenario of the multiplexing between HARQ-ACK and PUSCH with different priorities,**    + **RAN1 should confirm the working assumption of reusing Rel-15 timeline conditions for multiplexing HARQ-ACK and PUSCH can be reused.**   + **If multiplexing timeline conditions are not met 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).** |
| China Telecom | **Proposal 2: Multiplexing for channels with different priorities is allowed only when the ending symbol of PUCCH or PUSCH resource carrying the multiplexed UCI is no later than the ending symbol of channel carrying HP traffic.** |
| CMCC | **Proposal 8: The following conditions need to be considered for multiplexing of HARQ-ACK into PUSCH with different priorities on top of reusing Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements:**   * **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** |
| TCL | **Proposal 3: 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.** |
| Xiaomi | ***Proposal 1: Confirm the working assumption to reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.***  ***Proposal 2:*** ***When the multiplexing timeline is not met, HP channels can be transmitted and LP channels is dropped.*** |
| Qualcomm | ***Proposal 14:* 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 7. d2 for LP CG-PUSCH and HP DG-PUSCH collision resolution   |  |  | | --- | --- | |  | d2 [symbols] | | **0** | **1** | | **1** | **2** | | **2** | **4** | | **3** | **8** |   ***Proposal 15:* 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.**  ***Proposal 16:* Confirm the working assumption made in #104-e to reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.** |
| LGE | **Proposal #3: Consider additional condition for the processing of inter-priority multiplexing and the latency requirement for HP UCI.**  **Proposal #4: Discuss and decide the overall multiplexing procedures/steps for the inter-priority multiplexing of UCIs on PUCCH/PUSCH.**   * **It is desirable to proceed the multiplexing and transmission at least for HP PUCCH/PUSCH (if the timeline requirements among the HP PUCCH/PUSCH are met) even in case when the timeline requirements with LP are not met.** |
| Sharp | **Proposal 1: Confirm the working assumption of reusing Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.**   * **The Rel-16 dropping rule is reused if the multiplexing timeline requirements are not met.** |
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## Multiplexing HARQ-ACK and SR with different priorities

## Inputs from Tdocs

**When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0**

* Opt.1: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource.
  + Opt.1a: The UE does not transmit negative SR.
    - DCM
  + Opt.1b: For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.
    - ZTE, CATT, Quectel, DCM
  + Opt.1c: For negative SR, the UE transmits SR and HARQ-ACK on the SR resource
    - Nokia, Xiaomi
  + Opt.1d: with a power boost
    - QC
* Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.
  + Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
    - E///, LGE
  + Opt.2b: Using 4 CS values as for SR+1-bit HARQ-ACK in Rel-15/16. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
    - Spreadtrum, LGE
  + Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.
    - HW, Spreadtrum, vivo, China Telecom, Intel, Pana, Sony
* Opt.3: No enhancement over Rel-16.
  + OPPO (R15 or R16 according to the number of PUCCH symbols.), Samsung
* Opt.4: using a padding bit to bring the final UCI payload to 3 bits if there are 2 UCI bits for HARQ/SR.
  + Apple

**When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1**

* Opt.1: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource.
  + Opt.1a: The UE does not transmit negative SR.
    - DCM
  + Opt.1b: For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.
    - ZTE, CATT, China Telecom, Sony, DCM
  + Opt.1c: For negative SR, the UE transmits SR and HARQ-ACK on the SR resource
    - Nokia, Xiaomi
* Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.
  + Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
    - E///
  + Opt.2b: Applying QPSK for SR+1-bit HARQ-ACK. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
    - LGE, WILUS
* Opt.3: For positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
  + Intel, QC, DCM
* Opt.4: For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
  + HW, Spreadtrum, vivo, Quectel, Pana
* Opt.5: No enhancement over Rel-16.
  + OPPO, Samsung
* Opt.6: using a padding bit to bring the final UCI payload to 3 bits if there are 2 UCI bits for HARQ/SR.
  + Apple

**When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0**

* Opt.1: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource.
  + Opt.1a: For positive SR, the UE transmits the PUCCH in the resource using PUCCH format 1 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.
    - ZTE, CATT
  + Opt.1b: SR and HARQ-ACK are multiplexed and modulated to be transmitted on the SR resource
* Opt.2: The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.
  + Opt.2a: If SR is positive, an offset (e.g. 1 PRB) is added to the starting PRB of the HARQ-ACK PUCCH resource.
    - E///, LGE
  + Opt.2b: Using 4 CS values as for SR+1-bit HARQ-ACK in Rel-15/16. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.
    - Spreadtrum
  + Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.
    - HW, Spreadtrum, vivo, Intel, Sony
  + Opt.2d: HP SR and LP HARQ-ACK are multiplexed by the Rel-15 cyclic shift only if latency requirement for HP SR is met. Otherwise, drop the LP HARQ-ACK and only transmit the HP SR on its resource.
* Opt.3: For positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
  + Nokia, China Telecom, Quectel, Xiaomi, QC, Sharp, DCM
* Opt.4: No enhancement over Rel-16.
  + OPPO, Pana, Samsung
* Opt.5: using a padding bit to bring the final UCI payload to 3 bits if there are 2 UCI bits for HARQ/SR.
  + Apple

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| --- | --- |
| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 7: For multiplexing HP SR and LP HARQ-ACK with PF0/PF1,***   * ***For the case of HP SR with PF0 vs LP HARQ-ACK with PF0, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15 if SR is positive and transmit only HARQ-ACK on HARQ-ACK resource if SR is negative (i.e. option 2c);*** * ***For the case of HP SR with PF0 vs LP HARQ-ACK with PF1, drop LP HARQ-ACK if HP SR is positive (i.e. option 4);*** * ***For the case of HP SR with PF1 vs LP HARQ-ACK with PF0, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15 if SR is positive and transmit only HARQ-ACK on HARQ-ACK resource if SR is negative (i.e. option 2c);*** * ***For the case of HP SR with PF1 vs LP HARQ-ACK with PF1, reuse the resource selection method in Rel-15.***   ***Proposal 8: For multiplexing HP SR and LP HARQ-ACK with PF2/PF3/PF4,***   * ***Adopt separate coding to HP SR and LP HARQ-ACK on one PUCCH resource*** * ***The PUCCH resource is selected from the dedicated PUCCH resource sets in the second PUCCH-Config for multiplexing HP HARQ-ACK and LP HARQ-ACK*** * ***The multiplexing is only allowed if the ending symbol of the PUCCH resource carrying multiplexed SR and HARQ-ACK is no later than the ending symbol of the PUCCH resource carrying SR.*** |
| OPPO | ***Proposal 1: Rel-15 or Rel-16 mechanism should be reused to support multiplexing of HARQ-ACK and SR with different priorities.***  ***Proposal 2: When PF0 is used by both HP SR and LP HARQ-ACK, whether to use Rel-15 mechanism or Rel-16 mechanism can be determined according to the number of PUCCH symbols. The details are summarized in the table 1.***  Table 1: Multiplexing of LP HARQ-ACK and HP SR   |  |  |  |  | | --- | --- | --- | --- | |  | | LP HARQ-ACK | | | PF 0 | PF 1 | | HP SR  (positive) | PF 0 | If , Rel-15 mechanism;  Otherwise, Rel-16 mechanism. | Rel-16 mechanism | | PF 1 | Rel-16 mechanism | Rel-15 mechanism | |
| Spreadtrum | 1. ***If a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, if SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.*** 2. ***To distinguish between HP SR and LP SR on HARQ-ACK with PF0, Opt. 2b can also be considered.*** 3. ***If a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, for positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.*** 4. ***If a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, if SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.*** |
| ZTE | ***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.* | |
| 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.***  ***Proposal 5: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, option 2c is adapted.***   * ***If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.***   ***Proposal 6: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, option 4 is adapted.***   * ***For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.***   ***Proposal 7: When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, option 2c is adapted.***   * ***If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.***   ***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.***   ***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.*** |
| CATT | ***Proposal 5: For multiplexing of HP SR and LP HARQ-ACK with PF0/1,***   * ***positive SR and HARQ-ACK are multiplexed on the SR resource;*** * ***for negative SR, the UE transmits only HARQ-ACK on the HARQ-ACK resource.***   ***Proposal 6: For multiplexing of HP SR and LP HARQ-ACK with PF2/3/4,***   * ***for positive SR, drop LP HARQ-ACK;*** * ***for negative SR, transmit only HARQ-ACK on the HARQ-ACK resource.***   ***Proposal 7: 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*** |
| 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)*** |
| E/// | [Proposal 7 When PUCCH with HP SR overlaps with PUCCH with LP HARQ-ACK:](#_Toc68676144)  [ 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 (i.e. Opt. 2a).](#_Toc68676145)  [ 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 (i.e. Opt. 2a).](#_Toc68676146)  [Proposal 8 When PUCCH with HP HARQ-ACK/SR overlaps with PUCCH with LP HARQ-ACK:](#_Toc68676147)  [ 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.](#_Toc68676148) |
| 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.** |
| China Telecom | **Proposal 4: Resource selection is adopted in Rel-17 when a PUCCH carrying HP SR overlaps with a PUCCH carrying LP HARQ-ACK:**   * **When HP SR is positive, SR resource is used for the transmission.**   + **If SR resource corresponds to PF0, positive HP SR and LP HARQ-ACK are multiplexed using the cyclic shift values the same as in Rel-15.**   + **If SR resource corresponds to PF1, HARQ-ACK is transmitted on the SR resource to indicate the positive SR.** * **When HP SR is negative, the UE transmits only LP HARQ-ACK on the HARQ-ACK resource.** |
| Quectel | **Proposal 8**: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, Opt.1b (i.e., The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource, and the UE transmits only HARQ-ACK on the HARQ-ACK resource for negative SR) is supported.  **Proposal 9**: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, Opt.4 (i.e., for positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource) is supported.  **Proposal 10**: When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, Opt 3 (i.e., for positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource) is supported. |
| Xiaomi | ***Proposal 7:*** ***When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/PF1, support Opt1 and Opt 1c.***  ***Proposal 8:*** ***Power boosting is not needed to transmit multiplexed payload for*** ***HP SR and LP HARQ-ACK.***  ***Proposal 9:*** ***when a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0,*** ***support Opt 3, that is, for positive SR, transmit HARQ-ACK on the SR resource. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.*** |
| Intel | **Proposal 10:**  **HP SR PF0, LP HARQ PF0**:   * If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.   **HP SR PF0, LP HARQ PF1**:   * For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource   **HP SR PF1, LP HARQ PF0**:   * If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on 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. | |
| Qualcomm | ***Proposal 7*: 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 8*: In NR Rel-17, for the case of multiplexing 1 bit SR and up to 2 bits HARQ-ACK with different priorities in a PUCCH format 0, adopt the multiplexed payload to CS indices mapping as shown in Fig 17 and Fig 18.**  ***Proposal 9*: 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.** |
| Panasonic | **Proposal 9: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, the SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.**  **Proposal 10:**   * **When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, either of following options is supported.**   + **Option 4: For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.**   + **Option 5: No enhancement over Rel.16**   **Proposal 11: When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, no enhancement is necessary over Rel.16.**  **Proposal 12:**   * **When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, either of following options is supported.**   + **Option 1: Same multiplexing mechanism as in Rel.15/16.**   + **Option 2: The SR and HARQ-ACK are multiplexed and transmitted on the SR resource.**     - **1-bit for LP HARQ-ACK information bits are appended to SR information bits. For 2-bits HARQ-ACK information, bundling is used.**   **Proposal 13:**   * **When a PUCCH carrying HP SR with PF0 or PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF2, 3, or 4, following options is supported.**   + **The SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource if the latency condition is satisfied; otherwise, LP HARQ-ACK is dropped and HP SR is transmitted.**   **Proposal 14:**   * **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.** |
| Samsung | **Proposal 6: Drop LP HARQ-ACK PUCCH when a LP HARQ-ACK PF0/1 overlaps with a HP SR PUCCH.**  **Proposal 7: Support multiplexing of LP HARQ-ACK and HP SR when HARQ-ACK is transmitted on PUCCH format 2/3/4**   * **Use Rel-15 mechanism as a baseline assuming HARQ-ACK and SR have the same priority.** * **FFS: how to ensure the latency and reliability of HP SR.** |
| Sony | **Proposal 4: When HP SR using PF0 multiplexes with LP HARQ-ACK using PF0:**   * **If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15.** * **If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.**   **Proposal 5: When HP SR using PF0 multiplexes with LP HARQ-ACK using PF1:**   * **The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource** * **For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.**   **Proposal 6: When HP SR using PF1 multiplexes with LP HARQ-ACK using PF0:**   * **If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15.** * **If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.** |
| LGE | **Proposal #10: Consider to support Opt 2b for the combinations of {SR PF0 + HARQ-ACK PF0} and {SR PF0 + HARQ-ACK PF1} and {SR PF1 + HARQ-ACK PF0}, to ensure HP SR reliability as well as to keep PUCCH resource overhead.**  **Proposal #11: Consider to support Opt 2a for the combinations of {SR PF0 + HARQ-ACK PF0} and {SR PF0 + HARQ-ACK PF1} and {SR PF1 + HARQ-ACK PF0}, to guarantee LP HARQ-ACK performance on top of HP SR reliability.** |
| Sharp | **Proposal 5: When a PUCCH carrying HP SR with PF1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0,**   * **Transmit LP HARQ-ACK on the HP SR resource for positive HP SR, and** * **Transmit LP HARQ-ACK on the LP HARQ-ACK resource for negative HP SR.**   **Proposal 6: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0,**   * **Multiplex positive HP SR on LP HARQ-ACK PUCCH by a CS is preferred, esp. if different CS or transmit power is applied to differentiate a HP positive SR from a LP positive SR.** * **Alternatively, multiplex positive HP SR and LP HARQ-ACK on a HP SR PUCCH can be considered only if a HP SR PUCCH PF0 resource is configured with multiple reserved CS values.**   **Proposal 7: When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF1, the Rel-16 dropping behaviour may be applied.**   * **If multiplexing timeline is satisfied, positive HP SR and LP HARQ-ACK multiplexing on the HP SR PUCCH with PF0 can be considered only if the HP SR PUCCH PF0 resource is configured with multiple reserved CS values.**   **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.**  **Proposal 8: For multiplexing of HP HARQ-ACK, LP HARQ-ACK and SR, the multiplexing order and SR bit generation methods should be further clarified.** |
| DOCOMO | **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** | * Opt.1a (2nd preference): For positive SR, 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. For negative SR, the UE does not transmit negative SR but transmits HARQ-ACK bit(s) on URLLC SR PF0 resource.. * Opt.1b (1st preference): For positive SR, 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. For negative SR, the UE transmits only HARQ-ACK on the HARQ-ACK resource. | * Opt 3: 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 1a (2nd preference):   + 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.1c/Opt.3 (1st preference): 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 8: We propose to support Option 2b for multiplexing with HP-SR with PF0 and LP-HARQ with PF1.***   + ***To multiplex with HP-SR with PF0 and LP-HARQ with PF1, use the HARQ-ACK resource.***      - ***Applying QPSK for SR+1-bit HARQ-ACK. For the case of 2-bit HARQ-ACK, the HARQ-ACK is reduced/compressed to 1-bit.*** * ***Proposal 9: To multiplex with HP-SR with PF1 and LP-HARQ with PF0, reuse multiplexing rule for HP-SR with PF0 and LP-HARQ with PF0.*** |
| Apple | **Proposal 4-1: For {HP SR at PUCCH Format 0, LP HARQ-ACK at PUCCH Format 0}, or {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 1}, or {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 0}, {HP SR at PUCCH Format 1, LP HARQ-ACK at PUCCH Format 0},**   * **If there are 2 HARQ-ACK bits, then the 1 SR bit is included in the payload, bits is used to look up a HP PUCCH resource.**    + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, 3 bits are counted in the payload.** * **If there are 1 HARQ-ACK bit, 1 SR bit, then 1 padding bit included with them, bits is used to look up a HP PUCCH resource.**   + **If such a HP PUCCH resource is not available, then the LP UCI is discarded; and the HP UCI is carried over its configured PUCCH resource.**   + **If such a HP PUCCH resource is available, then 3 bits are counted in the payload (1 HARQ-ACK bit + 1 SR bit + 1 padding bit).** |

## 1st round proposals and discussions

Proposal for 1st round discussion:

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

* Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.
* Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.
* Opt.3: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

Proposal for 1st round discussion:

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

* Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.
* Opt.4: For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.
* Opt.5: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

Proposal after 1st round discussion:

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

* Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK 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, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.~~
* Opt.5: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

Proposal for 1st round discussion:

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

* Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK 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: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

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| Company | Comments |
| Sony | Agree to all 3 proposals |
| QC | For proposal 1, we cannot accept this proposal. It seems the down selection is purely based on # supporting companies, without much technical discussion. We have following questions for proposal 1.  Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource – Question: SR resource is only 1 single CS in one RB, how to use 1 CS to transmit positive SR + up to 2 bits HARQ-ACK? What is the motivation to apply RB selection between positive and negative SR. why not just transmit the up to 3 bits SR + HARQ-ACK in one RB?  Option 2c: What is the difference between this option and Rel-15 baseline? To me, “If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource” this is exactly Rel-15 behavior.  No matter which option we take, without power boost, how to guarantee the HP SR performance?  For proposal 2, again, we cannot accept the proposal in current form. We have a few questions as below.  Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource – Question: Again, SR resource in PF0 is only 1 CS within 1 RB, how to transmit positive SR + up to 2 bits HARQ-ACK with 1 CS? Does it mean transmit positive SR and HARQ-ACK in the RB of SR. If yes, option 1b is performing RB selection to transmit positive or negative SR, in the RB of SR, transmit HARQ-ACK is enough, what does it mean by “transmit positive SR and HARQ-ACK on SR resource”?  Option 4: if UE still have power headroom, why drop LP HARQ-ACK? Why not transmit them both with a power boost?  For proposal 3, is there a typo in the proposal? This should be HP SR with PF1 overlap with LP HARQ-ACK in PF1? |
| CATT | Fine with the proposals. |
| Quectel | We are generally fine with the proposals. Only a clarification question: is the down selection to be performed at this meeting or next meeting? |
| DOCOMO | Support the three proposals |
| Panasonic | We are fine with FL proposals. |
| Nokia/NSB | **On the first proposal – not agree**:  Since there is a way to multiplex SR with PF0 and HARQ-ACK with PF0 on PF0 (which corresponds to the HP channel here) based on Rel-15, we prefer to leverage that and transmit both SR and HARQ-ACK on the SR resource (to guarantee the reliability and latency of SR) regardless of whether SR is negative or positive. This is basically the corresponding Opt.1c under Opt.1 (listed above): For negative SR, the UE transmits SR and HARQ-ACK on the SR resource. **Therefore, we think Option 1c should replace Option 1b (or at least added) to take the Rel-15 multiplexing operation into account.**  **On the second proposal – not agree:**  Since there is a way to multiplex SR with PF0 and HARQ-ACK with PF1 on PF0 (which corresponds to the HP channel here) based on Rel-15, we prefer to leverage that and transmit both SR and HARQ-ACK on the SR resource (to guarantee the reliability and latency of SR) regardless of whether SR is negative or positive. This is basically the corresponding Opt.1c under Opt.1 (listed above): For negative SR, the UE transmits SR and HARQ-ACK on the SR resource. **Therefore, we think Option 1c should replace Option 1b (or at least added) to take the Rel-15 multiplexing operation into account.**  **On the third proposal – agree (but clarification needed):**  We have a similar question as QC, i.e. whether this is the PF1 vs. PF1 case or not, as in Opt.2c there is “ … in the same way as Rel-15”, and this rule is only applicable for SR with PF1 vs. HARQ-ACK PF1 (of same priority) in Rel-15. Anyhow, we are supportive of such a rule for both cases (SR with PF1 and HARQ-ACK with PF1/PF0) based on the Rel-15 handling when SR and HARQ-ACK are multiplexed on PF1 (which corresponds to the HP channel here). |
| OPPO | Partially agree to 3 proposals with small modification.  Generally, to reduce complexity of spec and implementation, existing procedure, R15 multiplexing or R16 prioritization procedure, should be reused.  For proposal 1, comparing with R15 multiplexing procedure, R16 prioritization procedure leads information loss of LP HARQ-ACK. So R15 multiplexing procedure can be considered around the premise on high reliability transmission of HP SR.  To be specific, when both HP SR and LP HARQ-ACK using PF 0, whether to use Rel-15 mechanism or Rel-16 mechanism can be determined according to the number of PUCCH symbols. The reliability of PF0 depends on the number of PUCCH symbols. If the number of LP PUCCH symbols is not less than the HP PUCCH symbols, using LP PUCCH to transmit HP SR and LP HARQ-ACK will not lead to the reliability loss of HP SR and avoid the dropping of LP HARQ-ACK.  So we suggest to modify Opt 3 as:  New Opt 3: Reuse R15 multiplexing or R16 prioritization procedure.  For proposal 2, Opt.4 is totally the same as R16 prioritization procedure, so one option, i.e. Opt.4 or Opt.5, is enough.  We suggest to delete Opt.4 but leave Opt.5 to align the wording of other proposals:  ~~Opt.4: For positive SR, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.~~ |
| Ericsson | Proposal 1: we don’t agree.   * In general, the proposal seems to use suggest to do as in Rel-15 (OK), or do something different as in Rel-15 (Opt. 1b) which it is not clear to us why we should choose that solution. * More details, Opt. 1b is different from Rel-15 and has the same issue as limited number of CS as in Rel-15. If we are going to do something different, it is better not to be at the cost of UE multiplexing capacity. * Opt. 2c/opt. 3: Not clear the difference. Aren’t both Rel-15? Or does Opt. 3 mean to drop LP HARQ-ACK as in Rel-16?   Proposal 2: we don’t agree.   * Opt. 1b: similar comment as above. * Opt. 4: Disagree. As we explained in other sections, e.g. 2.2.2, it is important to have a multiplexing solution for case of HP SR overlap with LP HARQ. Dropping based solution as proposed here is very costly for NW in term of resource allocation.   Proposal 3: we don’t agree.   * Opt. 3: doesn’t work for the same reason as was discussed in Rel-15 due to ambiguity. We don’t need to discuss solutions that have same problems. * Opt. 2c/opt. 3: Not clear the difference. Aren’t both Rel-15? Or does Opt. 3 mean to drop LP HARQ-ACK as in Rel-16?   General comment on proposals:   * It would be good to clarify more clearly to main categories:   + 1) As in Rel-15   + 2)Do enhancements   On second categories, to qualify the candidate options, the solutions at minimum should not reduce system multiplexing capacity, and cause ambiguity. Then, the comparison would be based on assessment of complexity and gain. |
| ITRI | Support the proposals |
| ZTE | Support the first and second proposals;  Not support the third proposal. |
| Intel | Support the proposals |
| Sharp | Support the proposals |
| LG | We are not supportive to the proposals, and it seems some technical discussions.  Our preferences are as below:   * For HP SR PF0 + LP HARQ-ACK PF0:   Prefer Opt.2a or Opt.2b.   * For HP SR PF0 + LP HARQ-ACK PF1:   Prefer Opt.2a or Opt.2b.  Also fine with Opt.4.   * For HP SR PF1 + LP HARQ-ACK PF0:   Prefer Opt.2a or Opt.2b.  Also supportive to Opt.3.  One question to Opt.1b for HP SR PF0 + LP HARQ-ACK PF0 and for For HP SR PF0 + LP HARQ-ACK PF1:  How to obtain 2 or 4 CS values on HP SR PF0 for mapping/transmitting of 1 or 2 bits for LP HARQ-ACK? |
| Apple | We don’t support the proposal. In our view, using a padding bit to bring the UCI bits to 3 bits is a far more simpler solution |
| Huawei | Support the 3 proposals |
| Lenovo, Motorola Mobility | In our view, RAN1 should discuss how to determine a PUCCH resource in general, when mixed UCI including at least LP HARQ-ACK and HP SR is transmitted:   1. A PUCCH resource to multiplex LP HARQ-ACK and HP SR 2. A PUCCH resource to multiplex of LP HARQ-ACK, HP HARQ-ACK, and HP SR   The PUCCH resource determination principle should be consistent for different cases of overlapping PUCCH format combinations. |
| Samsung | Not support  As we commented in 2.2.1, similar as 2 bits HARQ-ACK multiplexing, these cases are corner cases with no practical impact. These cases require the following conditions to be satisfied simultaneously and the overall probability is much smaller than the LP HARQ-ACK BLER.   1. UL URLLC traffic arrives (positive SR) when UE has eMBB traffic 2. 1 or 2 bits for LP HARQ-ACK 3. 2 PUCCHs overlap in time 4. No overlapping HP PUCCH 5. No overlapping PUSCH 6. Multiplexing is supported for LP HARQ-ACK and HP SR on a PUCCH.   Further, these cases can become complicated when there are more than two overlapping channels as we discussed in our contribution. Their support would require a large amount of overall Rel-17 intra-UE multiplexing complexity for the least/no benefit. We don’t think such optimizations are needed and they are detrimental to deployments. The default behavior is to follow Rel-16 and drop LP HARQ-ACK with the worst consequence of 1-2 PDSCH retransmissions. |
| vivo | Fine with the proposals. |
| Spreadtrum | Support the proposals. |
| APT | Fine with the proposals. |
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## 2nd round proposals and discussions

The second round discussion is for correcting the proposals.

* Companies do not need to repeat your inputs for the 1st proposal
* The 2nd proposal is modified as below to remove the redundant Option 4 and add Option 3 in the list. Please provide your comments.
* Option 2c in the 3rd proposal is questioned by some companies. Proponents of Option 2c are encouraged to explain it.

Improved proposal 2 for 2nd round discussion:

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

* Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK 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, transmit SR on the SR resource and drop HARQ-ACK. For negative SR, transmit HARQ-ACK on the HARQ-ACK resource.~~
* Opt.5: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

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| Company | Comments |
| Sony | We are fine with the “Improved Proposal 2” above. |
| QC | Option 1b and option 3 seems almost the same. Can FL or someone please clarify that is the difference between them? Is the difference that in option 1, when SR is positive, HARQ-ACK is transmitted with CS={1,4,7,10}, while in option 3, they are transmitted still with CS={0,3,6,9} when SR is positive? If so, what is the advantage in option 1b to do the extra 1 CS rotation? |
| Apple | In general, we don’t favor channel selection, channel selection has created problem for UL skipping, we would like to deal with such an issue in Rel-17. |
| Sharp | Option 1b and Option 3 seems the same.  In order to multiple or report HARQ-ACK on a positive HP SR resource with PF0, multiple cyclic shifts need to be reserved for the HP SR PUCCH resource. |
| DOCOMO | Support the improved proposal. However, we are not sure the difference between Opt.1b and Opt.3. |
| Samsung | Acceptable to make progress. Our preference is Opt.5. Also, we share similar view as Apple.    Regarding the FFS, we have commented in the last meeting and discussed in our contribution, when considering other overlapping channel(s) the multiplexing can become very complicated. It is better to have a clean and simply solution for 2 overlapping channels. |
| Quectel | Clarifications are needed between Option 1b and Option 3. |
| vivo | we are not sure the difference between Opt.3 and Opt.5. |
| ITRI | Share the same views with QC and Sharp, the difference between option 1b and and option 3 should be clarified. |
| Intel | Support the intention, but clarification is needed as mentioned above by the companies |
| CATT | We are fine with the proposal in general and also do not see the difference between Opt. 1b and Opt. 3. |
| Nokia | As we already explained, since there is a way to multiplex SR with PF0 and HARQ-ACK with PF1 on PF0 (which corresponds to the HP channel here) based on Rel-15, we prefer to leverage that and transmit both SR and HARQ-ACK on the SR resource (to guarantee the reliability and latency of SR) regardless of whether SR is negative or positive. This is basically the corresponding Opt.1c under Opt.1 (listed above). For negative SR, the UE transmits SR and HARQ-ACK on the SR resource. Therefore, we think Option 1c should replace Option 1b or at least added to take the Rel-15 multiplexing operation into account. |
| MediaTek | Fine with the proposal. Our preference is Opt. 5. |
| LG | For this combination, as indicated in 1st round, our preference is still Opt.2a or Opt.2b to ensure HP SR reliability, and we are also fine with Opt.4 in terms of keeping the similar behavior with Rel-15/16.  In addition, we also think Opt.1b and Opt.3 seem the same, and need clarification on how to obtain 2 or 4 CS values on HP SR PF0 resource for mapping/transmitting of 1 or 2 bits for LP HARQ-ACK. |
| ZTE | Fine with the “Improved Proposal 2” above.  From my perspective, option 1b emphasis the multiplexing SR with HARQ which aligns the section 9.2.5.1 of 38.213, while option 3 mentions only transmitting HARQ-ACK on the SR resource which aligns section 9.2.3 of 38.213. The components support option 3 could further clarify this.  If option 1b assumes the CS mapping {1,4,7,10} but option 3 assumes {0,3,6,9}. There is the difference. But if two options share the same CS mapping, they are the same.  The {1,4,7,10} is from the section 9.2.5.1 of 38.213 which related to UE procedure for multiplexing HARQ-ACK or CSI and SR in a PUCCH. {0,3,6,9} is from section 9.2.3 of 38.213 which is related to UE procedure for reporting HARQ-ACK.  Option 1b is just following the traditional CS mapping principle just move the resource to HP SR resource to keep the UCI reliability.  For the interaction between channel selection and UL skipping, if MAC layer is clever, the possible problem will be easy to be solved. |
| Huawei | In principle ok, but not clear about the difference between Opt.1b and Opt.3. |

## 3rd round proposals and discussions

To remove the nealy-redundant and unclear options, the following proposals are suggested.

Proposal for 3rd round discussion:

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

* Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource.
* Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource.
* Opt.3: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

Proposal for 3rd round discussion:

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

* ~~Opt.1c: For negative SR, the UE transmits SR and HARQ-ACK on the SR 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.5: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

Proposal for 3rd round discussion:

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

* ~~Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK 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: No enhancement over Rel-16.
* FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?

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| Company | Comments |
| Sony | **For the 2nd Proposal, i.e. HP SR PF0 + LP HARQ-ACK PF1**  The 2nd round proposal had Opt. 1b not Opt. 1c (as shown strike out in 3rd round proposal). As ZTE pointed out there is a difference between Opt. 1b and Opt. 3, that is:   * Opt. 1b: Positive SR and HARQ-ACK are multiplexed and transmitted in SR resource in PF0. That is:   + 1 SR + 1 HARQ-ACK, use *mcs* = {3, 9}   + 1 SR + 2 HARQ-ACK, use *mcs* = {1, 4, 7, 10} * Opt. 3: Positive SR, ***only*** HARQ-ACK is transmitted in the SR resource (i.e PF0). That is:   + 1 HARQ-ACK, use *mcs* = {0, 6}   + 2 HARQ-ACK, use *mcs* = {0, 3, 6, 9}   For Opt. 3, positive SR is not represented using CS in PF0 but is implicitly indicated by using PF0 whilst negative SR is implicitly indicated by using PF1.  We are fine either Opt. 1b or Opt. 3. However, it is good to give other companies the opportunity to consider this difference.  **For the 3rd Proposal, i.e. HP SR PF1 + LP HARQ-ACK PF0**  Same reasoning between Opt. 2c and Opt. 3.  We are fine with only Opt. 3 on the table but it will be good that this slight difference is pointed out and give an opportunity for others to consider. |
| OPPO | For proposal 1, comparing with R15 multiplexing procedure, R16 prioritization procedure leads information loss of LP HARQ-ACK. So R15 multiplexing procedure can be considered around the premise on high reliability transmission of HP SR. So, we suggest to make modification of Opt.3  Proposal for 3rd round discussion:  When a PUCCH carrying HP SR with PF0 overlaps with a PUCCH carrying LP HARQ-ACK with PF0, down-select the following options:   * Opt.1b: The positive SR and HARQ-ACK are multiplexed and transmitted on the SR resource. For negative SR, the UE transmit only HARQ-ACK on the HARQ-ACK resource. * Opt.2c: If SR is positive, SR is multiplexed on HARQ-ACK resource in the same way as Rel-15. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource. * Opt.3: Reuse Rel-15 or Rel-16 mechanism. * FFS: Whether/How to differentiate HP SR and LP SR when multiplexed with LP HARQ-ACK?   Support proposal 2 and 3 |
| LG | To be frank, all of the above three proposals suggested by FL doesn’t include our first preferred options indicated in 1st and 2nd round. But, for the progress, we can live with the above three proposals with condition to clarify the CS mapping on HP SR PF0 resource as below.  Regarding the CS mapping by Opt.1b for HP SR PF0 + LP HARQ-ACK PF0 and by Opt.3 for HP SR PF0 + LP HARQ-ACK PF1, there is no reason to have different CS mapping between the two cases since mapping of LP HARQ-ACK on HP PF0 resource is the same for both cases. Given that, considering to use a same CS between the case of SR only and the case of SR + all NACKs, the following mapping is preferred (captured from Sony’s expression in above).   * + 1 HARQ-ACK, use *mcs* = {0, 6}   + 2 HARQ-ACK, use *mcs* = {0, 3, 6, 9} |
| Huawei | For the 1st and 2nd proposal, we in principle agree.  For the 3rd proposal, we DO NOT agree. The question is WHY Opt.2c was removed from the candidates? Opt.2c is the Rel-15 method, i.e., If SR is positive, SR is multiplexed on **HARQ-ACK resource**. If SR is negative, transmit only HARQ-ACK on HARQ-ACK resource. It is totally different from the Opt.3 to multiplex both on the **SR resource.**  Therefore, we recommend to resume Opt.2c for the 3rd proposal. |
| Panasonic | We are fine with three proposals. |
| Samsung | Acceptable for make progress. Our preference is to follow Rel-16 behavior (i.e. no enhancement over Rel-16 - those cases are rare and have smaller impact than typical BLER). |
| ZTE | Appreciate Sony to further clarify option 1b and 3.  Although we have known the difference between option 1b and option 3, we are fine with only Opt. 3 on the table for sake of progress.  Fine with the three proposals. |
| QC | We don’t agree with proposal 1. We think for this overlapping scenario, we can just reuse Rel-15 with a power boost. No need to do resource selection, which double the resource utilization. Not sure why that option was removed.  We are OK with proposal 2 and 3. |
| Quectel | For progress, we are fine with these three proposals. |
| DOCOMO | For the 1st and 3rd proposals, we are fine.  For the 2nd proposal, we slightly prefer to keep Opt.1b. From the ZTE’s clarification, we see there is not much difference between Opt.1b and Opt.3. However, Opt.1b seems more similar behavior to Rel-15 since positive SR is represented using CS in PF0. |
| Nokia/NSB | We can be fine with the first and second proposal for the sake of progress.  Support the third proposal.  As a general comment, for the scenarios where multiplexing would be adopted, it’s important to use HP PUCCH resource for the multiplexing. |
| Spreadtrum | Fine with the first and second proposal. For the third proposal, we agree with HW’s view. |
| Lenovo, Motorola Mobility | We don’t agree with the proposals. In our view, a PUCCH resource determination rule to multiplex LP HARQ-ACK with HP SR should be consistent for different cases (e.g. more than 1 HP SR, SR of PF0 and LP HARQ-ACK of more than 2 bits). Thus, a general PUCCH resource determination rule for LP HARQ-ACK and HP SR should be discussed. |
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## Multiplexing scenarios, rules and order (incl. more than two overlapping channels)

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 9: The discussion about multiplexing more than 2 PUCCHs should be postponed until the multiplexing rules for two colliding PUCCHs are agreed.*** |
| OPPO | ***Proposal 9: For more than two overlapping channels, timeline and procedure for multiplexing and prioritization specified in 38.213 can be reused.*** |
| 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.*** |
| ZTE | ***Proposal 7:*** *Determine the multiplexing rules for the UCI multiplexing rules of more than two overlapping PUCCHs with different priorities after the UCI multiplexing rules for two overlapping PUCCHs is clear.* |
| vivo | ***Proposal 17: To avoid the dropping of LP UCI, the overlapping handling order may need be reconsidered.*** |
| ATP | Proposal 9 A first UCI multiplexing procedure for low priority PUCCHs is performed as specified in Clause 9.2.5 in TS 38.213 first, and a second UCI multiplexing procedure for multiplexing high priority PUCCHs and the resulting low priority PUCCH is performed once a high priotiy PUCCH is scheduled, with the resulting low priority PUCCH from the first UCI multiplexing procedure included in the set of PUCCH resources over which the second UCI multiplexing procedure is performed. |
| E/// | [Proposal 1 Prioritize work to stablish early on a common understanding on the overall framework of the expected procedures than detailed solutions.](#_Toc68676138)  [Proposal 2 Investigate the candidate frameworks A1, A2, B1, B2 and their combinations for gain and complexity analysis, starting with B2 and A2-B2.](#_Toc68676139)  [Proposal 3 Consider investigating the complexity of potential features for multiplexing UCI with different priority in PUCCH/PUSCH.](#_Toc68676140)  [Proposal 11 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.](#_Toc68676151)  [Proposal 12 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.](#_Toc68676152)  [Proposal 13 For UCI multiplexing on PUSCH, one or more PUCCH can overlap with PUSCH where the corresponding UCI can be multiplexed in the PUSCH.](#_Toc68676153) |
| 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.*  ***Observation 2****: The straightforward method for multiplexing two Type-1 HARQ-ACK codebooks on a PUCCH by constructing two Type-1 HARQ-ACK codebooks separately as Rel-16 and pasting them together as a multiplexed HARQ-ACK codebook may lead to unnecessary redundancy.*  ***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 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 transmitting 1-bit indicator with multiplexed HARQ-ACK feedback as proposed in proposal 1 to explicitly indicate which codebook is bundled.*  ***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 | * **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.** |
| CMCC | **Proposal 2: The following conditions need to be considered for multiplexing of LP HARQ-ACK and HP HARQ-ACK/HP SR on top of reusing Rel-15 intra-UE PUCCH multiplexing timeline requirements:**   * **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 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.** |
| TCL | **Proposal 7: The scenario of multiplexing more than two overlapping channels should be further studied.** |
| Xiaomi | ***Proposal 3: When a LP PUCCH overlaps with multiple HP PUCCHs contained in multiple subslots, whether multiplexing timeline is met is only determined by the LP PUCCH and HP PUCCH(s) contained in one subslot, rather than by the LP PUCCH and HP PUCCH(s) in all the subslots.***  ***Proposal 12: 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.*** |
| Intel | **Proposal 11: P/SP CSI is dropped if its resource overlaps with HP SR or HP HARQ-ACK.**  **Proposal 12: Instead of two-step approach, consider joint multiplexing of UCIs of different priorities into a PUCCH resource if UE supports intra-UE multiplexing across different priorities.**  **Proposal 13: When UCIs of different priorities overlap and if at least one is based on a DCI, UE may drop the low priority UCI and transmit the high priority UCI, when timeline conditions are not satisfied.** |
| Samsung | **Observation 3: For determination of the PUCCH time unit for handling PUCCH collisions with different PUCCH time units (i.e. slot and sub-slot PUCCH configuration) of different priorities, 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 one HP HARQ-ACK PUCCH resource.** * **Case 3) Each HP sub-slot contains zero or more HP SR PUCCH resource and zero or one HP HARQ-ACK PUCCH resource.** * **Note: Multiplexing of PUCCH with different priorities is performed within a PUCCH time unit (i.e. either within a slot or a sub-slot). E.g. for each PUCCH time unit, put all the associated PUCCHs (e.g. for a same priority, associated PUCCHs are the PUCCHs within the PUCCH time unit) in the corresponding set Q and then reuse Rel-15/Rel-16 rules.** * **Aiming to reuse Rel-15/16 pseudo code for PUCCH multiplexing with limited optimization.**   **Proposal 8: 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.**   **Proposal 9: 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 HP HARQ-ACK PUCCH and LP HARQ-ACK, then multiplex resulting PUCCH and SR PUCCH (if there is overlapping)**   **Proposal 10: Determine order for resolving overlapping among HP/LP PUCCHs and HP/LP PUSCHs.** |
| 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.** |
| DOCOMO | **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.* |
| Leno/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, unless a PUCCH of low priority index for LP HARQ-ACK is limited up to a current sub-slot. |
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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.*

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*

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)*

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

## Inputs from Tdocs

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

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 12: 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 separate encoding the UCIs with different priorities on PUSCH, it should be discussed whether and how to increase the number of separately encoded UCIs for PUSCH.***  ***Proposal 11: Separate encoding is preferred for LP UCI and HP UCI multiplexing on PUSCH.***  ***Proposal 12: For separate encoding the UCI with different priorities on PUSCH, a beta-offset set to provide beta-offsets for LP UCI and HP UCI multiplexing on PUSCH should be indicated/configured by network.*** |
| APT | Proposal 5 Separate coding of high priority UCI and low priority UCI when multiplexed in a PUSCH is supported. |
| Nokia | * **Proposal 3.15: 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.** |
| 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 partially dropped if needed.** |
| Qualcomm | ***Proposal 4*: 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.** |
| Samsung | **Observation 1: Separate coding shows a gain over joint coding in case of RM coding.**  **Proposal 3: Support separate coding for UCIs with different priorities multiplexed on a PUCCH format 2/3/4 or a 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 both PUCCH format 0 and 1, modulation of 2 bits HARQ-ACK of a same priority can be reused.**   **Observation 2: Multiplexing of LP HARQ-ACK codebook and HP HARQ-ACK codebook with same and/or different HARQ-ACK codebook types can be enabled 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.** |
| Leno/Moto | * **Proposal 10:** UCI with different priorities that is multiplexed in PUSCH are separately encoded and rate-matched. |
| ITRI | **Proposal 5:**  Support separate coding for UCI with different priority indexes when they are multiplexed on a PUSCH. |

## 1st round proposals and discussions

Proposal for 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, support separate coding for the two HARQ-ACKs.

Support: Sony, CATT, Quectel, DCM, NEC, Pana, Nokia, OPPO, ITRI, ZTE, Intel, Sharp, LG, IDC, HW, Leno/Moto, Samsung, TCL, vivo, Spreadtrum, APT

Not support: QC

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| Company | Comments |
| Sony | Agree |
| QC | Unfortunately, this proposal is not acceptable to us, due to the following concerns.  First, what is the technical benefit to adopt the separate encoding? From performance point of view, separate encoding is worse then combination of joint+separate encoding, see simulation results in Section 3.2.1 in R1-2103166. From spec impact point of view, separate encoding has much larger spec impact than joint encoding. We don’t see any benefit to adopt separate encoding for this UCI mux on PUSCH use case.  PS: this is the list of spec impact we can think of for separate encoding. We’d like to see answers to following questions, before we can accept this proposal to adopt separate coding.   * How to signal multiple code rates for HP+LP UCI on PUSCH with UL-SCH? How to signal multiple code rates for HP+LP UCI on PUSCH without UL-SCH? Need double both RRC and DCI signalling overhead? * How to concatenate encoded HP and LP UCI bits? Any interleaving across HP and LP encoded bits to improve robustness to busty error/interference? * How to split/concatenate the HP+LP UCI between the two frequency hops (split between two hops first then concatenate or the other way), when hopping is enabled for HP+LP UCI PUSCH with UL-SCH, PUSCH without UL-SCH. * How to handle the following 4 combinations (puncture + rate match) cases for HP/LP on PUSCH   + <=2 bits HP A/N puncture CSI-2 or PUSCH, <=2 bits LP A/N puncture CSI-2 or PUSCH   + <=2 bits HP A/N puncture CSI-2 or PUSCH, >2 bits LP A/N rate match CSI-2 or PUSCH   + >2 bits HP A/N rate match CSI-2 or PUSCH, <=2 bits LP A/N puncture CSI-2 or PUSCH   + >2 bits HP A/N rate match CSI-2 or PUSCH, >2 bits LP A/N rate match CSI-2 or PUSCH * What is the additional/new rate matching equations for HP+LP UCI on PUSCH with UL-SCH, on PUSCH without UL-SCH * What are the new RE mapping rules to map HP+LP UCI on PUSCH with UL-SCH, or on PUSCH without-UL\_SCH? The new rules start to map HP A/N to which REs, followed by mapping LP A/N to which REs? What are the exact changes needed in the Pseudo codes in Section 6.2.7? * How to decide reference BPRE in power control with separate encoding, when HP+LP UCI transmitted on PUSCH with UL-SCH, or on PUSCH without UL-SCH?   Second, what is the motivation to adopt different design for UCI multiplexing on PUCCH and UCI multiplexing on PUSCH? For HP + LP A/N on PUCCH, combination of joint and separate coding is proposed. For HP + LP A/N on PUSCH, why adopt a different design? We think RAN1 should strive for a common design for these two cases. Like we commented for UCI mux on PUCCH, we can accept the combination of joint+separate encoding as a compromised solution, because it can offer the best performance. Based on the motivation to have a unified design for UCI on PUCCH/PUSCH, we propose the following:  **Proposal 1**: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, support combination of separate coding and joint coding for the two HARQ-ACKs.   * + FFS the condition for applying separate coding and joint coding.   + FFS how to multiplex the LP and HP HARQ-ACK after separate coding.   + FFS HARQ-ACK compression/bundling for joint coding.   FFS signaling mechanism to enable UE to perform separate coding only, joint coding only, or both for LP and HP HARQ-ACK multiplexing. |
| CATT | Agree |
| Quectel | We do not have strong view for this proposal. As different coding schemes are supported by UCI on PUCCH and UCI on PUSCH in Rel-15, we can accept this proposal. |
| DOCOMO | Support |
| NEC | Agree with the proposal. |
| Panasonic | We support the FL proposal. |
| Nokia/NSB | Support the proposal.  Overall, as pointed out by QC in the GTW call if possible, the same procedure should be applied for mapping on PUCCH and PUSCH. |
| OPPO | Support FL proposal |
| Ericsson | We think this discussion is related to Hp/LP HARQ-ACK multiplexing on PUCCH as discussed before.  We agree that we should treat them together. And also avoid complicated solutions due to low number of LP HARQ-ACK bits. |
| ITRI | Support the proposal |
| ZTE | Agree |
| Intel | Agree |
| Sharp | Agree |
| LG | Support the proposal. |
| InterDigital | Agree |
| Apple | We can treat the design together for PUCCH and PUSCH. If separate encoding is used, then HP HARQ goes to UCI Part I on PUCCH, LP HARQ goes to UCI part II on PUCCH; HP HARQ goes to UCI part 0 (HARQ part) on PUSCH, LP HARQ goes to UCI part I or UCI part II on PUSCH. |
| Huawei | Agree. Same view-point as 2.2.2, it is better to choose a unified solution for both PUCCH and PUSCH. |
| Lenovo, Motorola Mobility | Support the proposal |
| Samsung | Support.  Separate coding applies since LTE Rel-8 and since NR Rel-15 for UCI multiplexing on a PUSCH. Same principle should apply in NR Rel-17. LP/HP multiplexing is certainly not an issue justifying any change. Also, due to different beta\_offsets, even Rel-15 HARQ-ACK can be viewed as HP UCI and CSI can be viewed as LP UCI. |
| TCL | Support the proposal |
| vivo | support |
| Spreadtrum | Agree. |
| APT | Support. |

## Enhancements for multiplexing parameters

## Beta-offset value and configuration

#### Inputs from Tdocs

**Support Beta-offset =0?**

* Yes
  + HW, Spreadtrum, CATT, IDC, E///, Nokia, China Telecom, Pana, DCM, ITRI
* No
  + ZTE, Sharp

**Other Beta-offset values**

* 0.5
  + Spreadtrum
* 0.8
  + Spreadtrum
* Non-numerical
  + Sony

**Separate configurations of Beta-offset values for different priorities.**

* + OPPO, CATT, MTK, ATP, IDC, E///, Nokia, China Telecom, Intel, QC, Sony, LGE, DCM, ITRI

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 10: For multiplexing LP HARQ-ACK on HP PUSCH, support beta-offset = 0.*** |
| 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.*** |
| Spreadtrum | 1. ***gNB can set the smaller beta\_offset values for multiplexing LP HARQ-ACK in a HP PUSCH, such as 0.8, 0.5 and 0.*** |
| ZTE | ***Proposal 9: The beta-offset should not be used to disable the intra-UE multiplexing UCI with data.*** |
| CATT | ***Proposal 12: For a UE supporting multiplexing between different priorities, consider enhancements to UCI multiplexed on PUSCH based on independent beta offsets for different priority combination of UCI and PUSCH.***  ***Proposal 13: An additional UL DAI bit field can be considered to be added in the UL DCI for multiplexing PUCCH and PUSCH with different priority.*** |
| MTK | 1. Two sets of beta-offset could be defined one for high priority UCI and one for low priority UCI multiplexing. |
| APT | Proposal 7 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. |
| IDC | ***Proposal 15: A beta\_offset indicator field set to 0 indicates that UE disables multiplexing of LP HARQ-ACK in HP PUSCH.***  ***Proposal 11: 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 12: 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.*** |
| E/// | [Proposal 14 For UCI multiplexing on PUSCH, a different target code rate and beta factor is considered for high priority HARQ-ACK.](#_Toc68676154)  [Proposal 15 Support dynamically enable/disable multiplexing by beta factor (e.g. beta=0 to disable mux)](#_Toc68676155) |
| Nokia | * **Proposal 3.11: For the scenarios of multiplexing HARQ-ACK bits in DG PUSCH of different priorities, gNB dynamically indicates via beta\_offset (e.g. beta\_offset = 0) in the corresponding scheduling DCI whether to multiplex HARQ-ACK in PUSCH of different PHY priority or not. FFS whether to support multiplexing of HARQ-ACK bits on CG PUSCH of a different PHY priority.** * **Proposal 3.12: For the scenarios of multiplexing HARQ-ACK bits in PUSCH of different priorities, RAN1 should specify:**   + **two additional sets of beta\_offset values for:**     - **multiplexing low-priority HARQ-ACK in high-priority PUSCH;**     - **multiplexing high-priority HARQ-ACK in low-priority PUSCH;**   + **for multiplexing of low-priority and high-priority HARQ-ACK, the beta\_offset indicator field in the DCI points to the respective two sets of beta\_offset values to be applied independently for low- and high-priority HARQ-ACK;** |
| China Telecom | **Proposal 5: Up to four sets of beta-offset values can be configured by RRC signalling corresponding to the four cases for multiplexing a LP HARQ-ACK in a HP PUSCH, a HP HARQ-ACK in a LP PUSCH, a HP HARQ-ACK in a HP PUSCH, a LP HARQ-ACK in a LP PUSCH.**   * **Beta-offset =0 can be configured in the value set for multiplexing a LP HARQ-ACK in a HP 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 partially dropped if needed.** |
| Qualcomm | ***Proposal 10*: 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** |
| Panasonic | **Proposal 15:**   * **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.** * **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 should be supported.** |
| Sony | **Proposal 7: For multiplexing of UCI into PUSCH of different L1 priorities, the gNB is able to configure four different sets of ** offsets.**  **Proposal 8: For multiplexing of UCI into PUSCH of different L1 priorities, the gNB is able to configure separate ** offsets for different PUSCH L1 priorities.**  **Proposal 10: The gNB dynamically indicates whether to enable/disable multiplexing of UCI bits into PUSCH of different L1 priorities.**  **Proposal 11: 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 and instead use prioritisation. That is:**   * **If *beta\_offset indicator* is numerical then:**   + **LP UCI is multiplexed into HP PUSCH using the indicated ** offset value**   + **HP UCI is multiplexed into LP PUSCH using the indicated ** offset value** * **If *beta\_offset indicator* = “NOT MULTIPLEX” then:**   + **For the case of LP UCI & HP PUSCH, the LP UCI is dropped and HP PUSCH is transmitted**   + **For HP UCI & LP PUSCH, the LP PUSCH is dropped and HP UCI is transmitted on PUCCH** |
| 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, to ensure reliability/protection of HP PUSCH.** |
| Sharp | **Proposal 10: Do not support beta offset = 0 for UCI disabling signalling.** |
| DOCOMO | **Proposal 8:**   * *Support beta-offset =0 or a value disabling the UCI multiplexing on PUSCH of different priorities*   **Proposal 9:**   * *Introduce new RRC parameter for the new beta-offset range (i.e. 0 < beta-offset < 1) in order to let UE to use different beta-offset values for different multiplexing scenario.* |
| ITRI | **Proposal 6:**  When UCIs corresponding to different priorities are decided to multiplex in a PUSCH:   * The beta-offset of UCI with the same priority as PUSCH is determined by RRC; while the beta-offset of UCI with different priority from the PUSCH is determined by the UL grant DCI.   **Proposal 7:**  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. |
|  |  |

#### 1st round proposals and discussions

Proposal for 1st round discussion:

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

Proposal after 1st round discussion:

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 HARQ-ACK on the PUSCH with same priority
* ~~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~~

Support: Sony, QC, CATT, Quectel, DCM, NEC, Pana, Nokia, OPPO, E///, ITRI, ZTE, Intel, Sharp, LG, IDC, HW, Leno/Moto, Samsung, vivo, Spreadtrum, APT

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| --- | --- |
| Company | Comments |
| Sony | Agree |
| QC | We support this FL proposal |
| CATT | Agree with the proposal in principle and “/UCI” can be removed. |
| Quectel | Support |
| DOCOMO | Support the proposal in general, while single configuration may be enough for LP UCI on LP PUSCH case and HP UCI on HP PUSCH case as in Rel-16. However, we are fine with the current proposal description since it is “up to four sets.” |
| NEC | Agree with the proposal. |
| Panasonic | We are fine with the FL proposal. |
| Nokia/NSB | In principle support the proposal.  However, as already supported in Re-15/16, one configuration should be enough for multiplexing LP HARQ-ACK on LP PUSCH and HP HARQ-ACK on HP PUSCH. As discussed in our Tdoc [R1-2102820], specifying two additional sets of beta\_offset for multiplexing LP HARQ-ACK on HP PUSCH and multiplexing HP HARQ-ACK on LP PUSCH should be sufficient.  “/UCI” should be removed from the proposal as scenarios with other UCIs (other than HARQ-ACK) have not been discussed. |
| OPPO | Support FL proposal |
| Ericsson | We share the same view as Nokia. We are in principle OK, but it is not clear to use why there is a need for 3 categories, instead of two. |
| ITRI | Support the proposal |
| ZTE | Support the intention of the proposal. For the same priority multiplexing, we can simply use the Rel-15 principle and no need to distinguish the LP and HP. That is, the cases could be:   * Multiplexing HARQ-ACK/UCI on the same priority PUSCH * Multiplexing LP HARQ-ACK/UCI on HP PUSCH * Multiplexing HP HARQ-ACK/UCI on LP PUSCH |
| Intel | Support |
| Sharp | Agree |
| LG | Support |
| InterDigital | Agree |
| Apple | We can finish joint/separate encoding discussion first, then come to this issue |
| Huawei | Support |
| Lenovo, Motorola Mobility | Support the proposal |
| Samsung | Support |
| vivo | support |
| Spreadtrum | Support |
| APT | Support |

## Separate configurations of alpha values?

#### Inputs from Tdocs

* Yes
  + Quectel, CMCC, LGE, Lenovo/Moto, ITRI
  + 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
  + Nokia, China Telecom
  + 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 |
| Nokia | * **Proposal 3.13: For the scenarios of multiplexing HARQ-ACK bits in a PUSCH of different priorities, do not support separate configurations of the scaling factor “alpha”.** |
| China Telecom | **Proposal 5: Up to four sets of beta-offset values can be configured by RRC signalling corresponding to the four cases for multiplexing a LP HARQ-ACK in a HP PUSCH, a HP HARQ-ACK in a LP PUSCH, a HP HARQ-ACK in a HP PUSCH, a LP HARQ-ACK in a LP PUSCH.**   * **Beta-offset =0 can be configured in the value set for multiplexing a LP HARQ-ACK in a HP PUSCH.** |
| Quectel | **Proposal 6**: Separate configuration of scaling factors (“alpha”) is supported for UCI-PUSCH multiplexing with different priority combinations. |
| CMCC | **Proposal 10: Support separate configuration of alpha for multiplexing with different priority combinations of HARQ-ACK and 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, to ensure reliability/protection of HP PUSCH.** |
| Leno/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. |
| ITRI | **Proposal 4:**  Support separate configuration of alpha for multiplexing with different priority combinations of HARQ-ACK and PUSCH. |

## Multiplexing enable/disable mechanism

## Inputs from Tdocs

Multiplexing enable/disable mechanism

* Option 1: By beta\_offset (e.g. beta=0 to disable mux)
  + CATT, IDC, E///, CMCC, Sony, DCM, ITRI, Nokia
* Option 2: By new DCI field
  + ZTE (in HP DCI or RRC), APT, IDC, Quectel, Intel, Samsung, ETRI
* Option 3: By RRC configuration
  + ZTE (in HP DCI or RRC), CATT, MTK, IDC (for CG PUSCH and SPS), CMCC, TCL, Xiaomi, Intel, QC, ETRI (when no DCI indication), Sharp

The arguments are similar to that for Section 2.3.

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| Company | Proposals/observations from Tdocs |
| ZTE | ***Proposal 10****: The indicator of intra-UE multiplexing UCI with data exists in the scheduling DCI or RRC parameter for the high priority transmission.* |
| CATT | ***Proposal 10: Semi-static RRC configuration to enable/disable the multiplexing between channels with different priorities is supported.***  ***Proposal 11: 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.*** |
| MTK | Dynamic indication of the multiplexing activation/de-activation is not supported. |
| APT | Proposal 8 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. |
| IDC | ***Proposal 13: DCI scheduling HP PUSCH indicates if UE multiplexes LP HARQ-ACK in HP PUSCH.***  ***Proposal 14: DCI indicating HP HARQ-ACK also indicates if UE multiplexes HP HARQ-ACK in LP PUSCH.***  ***Proposal 15: A beta\_offset indicator field set to 0 indicates that UE disables multiplexing of LP HARQ-ACK in HP PUSCH.***  ***Proposal 16: RRC configuration for each HP CG configuration includes an indication of whether the UE can multiplex LP HARQ-ACK in corresponding HP PUSCH.***  ***Proposal 17: RRC configuration of SPS with HP HARQ-ACK includes an indication of whether the UE can multiplex HP HARQ-ACK in LP PUSCH.***  ***Proposal 18: 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 19: Support multiplexing of high-priority SR in PUSCH by selection of DMRS sequence in PUSCH.*** |
| E/// | [Proposal 15 Support dynamically enable/disable multiplexing by beta factor (e.g. beta=0 to disable mux)](#_Toc68676155) |
| Quectel | **Proposal 7**: Dynamic enabling/disabling by DCI for UCI-UCI multiplexing and UCI-PUSCH multiplexing with different priorities is supported on top of RRC configuration. |
| CMCC | **Proposal 11: 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.** |
| TCL | **Proposal 5: RRC configuration for enabling UCI multiplexing on PUSCH with different priorities should be supported.** |
| Xiaomi | ***Proposal 11: 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.*** |
| Intel | **Proposal 9: DCI and higher layer indication can be provided to enable multiplexing of UCI onto DG PUSCH and CG PUSCH, respectively.** |
| Qualcomm | ***Proposal 17:* The Rel-17 intra-UE multiplexing feature is enabled/disabled via RRC configuration on per UE basis.**  ***Proposal 18:* 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.** |
| 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.** |
| Sony | **Observation 1: Disabling UCI multiplexing by indication ** =0 does not work when the UCI has High L1 Priority.**  **Proposal 10: The gNB dynamically indicates whether to enable/disable multiplexing of UCI bits into PUSCH of different L1 priorities.**  **Proposal 11: 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 and instead use prioritisation. That is:**   * **If *beta\_offset indicator* is numerical then:**   + **LP UCI is multiplexed into HP PUSCH using the indicated ** offset value**   + **HP UCI is multiplexed into LP PUSCH using the indicated ** offset value** * **If *beta\_offset indicator* = “NOT MULTIPLEX” then:**   + **For the case of LP UCI & HP PUSCH, the LP UCI is dropped and HP PUSCH is transmitted**   + **For HP UCI & LP PUSCH, the LP PUSCH is dropped and HP UCI is transmitted on PUCCH** |
| ETRI | **Proposal 9: 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.** |
| Sharp | **Proposal 3: RRC configuration is used to separately enable/disable of UCI multiplexing on PUSCH for each scenario.** |
| DOCOMO | **Proposal 8:**   * *Support beta-offset =0 or a value disabling the UCI multiplexing on PUSCH of different priorities* |
| ITRI | **Proposal 7:**  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. |
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## 1st round proposals and discussions

Proposal for 1st round discussion:

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, support RRC configuration as a baseline for gNB to enable/disable the multiplexing.

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

Proposal after 1st round discussion:

For multiplexing a ~~high-priority (HP) HARQ-ACK and a low-priority (LP)~~ HARQ-ACK into a PUSCH with different priorities in R17, at least support RRC configuration ~~as a baseline~~ for gNB to enable/disable the multiplexing.

* FFS whether or not to additionally introduce other ~~the~~ types of the mechanism, e.g. DCI indication, beta\_offset=0
* FFS: Interaction between the enable/disable mechanism and other multiplexing conditions
* FFS for other types of UCI.

Support: QC, CATT, Quetel, DCM, NEC, OPPO, ITRI, ZTE, Sharp, LG, HW, Leno/Moto, Samsung, TCL

Not support (dynamic indication should also be supported): Nokia, E///, Intel, IDC, APT

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| Company | Comments |
| Sony | We still prefer a dynamic indicator using an index in the beta\_offset table where one of the index points to NO MULTIPLEXING. NOTE: beta\_offset = 0 does not work for the case for HP HARQ-ACK multiplexing into LP PUSCH as this would lead to the HP HARQ-ACK being dropped.  It would also be good to clarify what it meant by “baseline” in this agreement. RRC configuration is anyhow needed even for dynamic indicator since gNB needs to configure the dynamic indicator for the UE. |
| QC | We support this FL proposal. RRC signaling has to be the baseline because this feature has to work with CG-PUSCH, SPS A/N, etc.  Whether DCI indication is needed can be FFS. In our view, we don’t see strong motivation to introduce DCI indication. Because UL grant has to arrive later than DL grants, when gNB schedule the UL grant, it already knows all the HP and LP A/N payload size, gNB can always schedule more RBs in PUSCH to accommodate UCI multiplexing. Our second concern on dynamic indication is that it increase UE implementation complexity, without strong necessity/motivation to do so. |
| CATT | Similar as the proposal in 2.3.2, “as a baseline” can be removed. In addition, “type of the mechanism” in the first sub-bullet is not clear. |
| Quectel | Similar comments to the proposal in 2.3.2 for multiplexing enabling/disabling on PUCCH. |
| DOCOMO | Fine with the proposal. Similar to 2.3.2, “as a baseline” can be removed to avoid any misunderstanding. |
| NEC | Agree with the proposal in general. Similar comments to the proposal in 2.3.2. |
| Panasonic | We are fine with FL proposal. |
| Nokia/NSB | Not support the proposal.  We prefer gNB can dynamically enabling/disabling multiplexing HARQ-ACK in PUSCH of different priorities via beta\_offset (i.e. beta\_offset=0 supported). In this way, the possible negative performance impacts in terms of latency and/or reliability on the high-priority channel can be avoided since the multiplexing decision is made by gNB. In addition, overall specification efforts can be reduced as some other discussions e.g. bundling/compressing LP HARQ-ACK can be avoided or simplified. |
| OPPO | Support FL proposal.  RRC configuration should be supported. And flexible multiplexing and prioritization switch is also necessary, especially when multiplexing condition is not satisfied.  For DCI indication, it does not work for configured grant case.  For multiplexing condition, it can be based on latency requirement and timeline. To be specific,   * If the ending symbol used for UCI transmission in a low-priority PUSCH is not later than the ending of high-priority PUCCH, multiplexing is applied. Otherwise, fallback to R16 prioritization. * If R15 timeline for multiplexing is satisfied, Multiplexing is applied. Otherwise, fallback to R16 prioritization. |
| Ericsson | We share similar view as Nokia. The proposal is better be formulate for dynamic indication. The need for RRC configuration for enabling/disabling should be understood as given. The discussion should be spent on dynamic indication that brings additional value as explained previously.  Please find below the updated proposal:  For enabling/disabling multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, support RRC configuration as a baseline, a dynamic mechanism for gNB to enable/disable the multiplexing.   * FFS the type of the mechanism for dynamic enabling/disabling of multiplexing, e.g. ~~DCI indication,~~ beta\_offset=0 * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI. |
| ITRI | This proposal seems only for the case when both LP and HP HARQ-ACKs are multiplexed in a PUSCH. Our understanding is that the enable/disable mechanism is for the HARQ-ACK multiplexing on PUSCH of different priorities. The scenario of this proposal should be clarified. |
| ZTE | We are fine with the proposal. DCI indication can be further studied. “as a baseline” should be kept. |
| Intel | Not support the proposal. We prefer dynamic enable/disable by DCI. The reasons are explained well by Ericsson and Nokia above |
| Sharp | Support the proposal |
| LG | Support the proposal. |
| InterDigital | Do not support the proposal. The updated proposal by Ericsson is a better direction, but beta\_offset=0 should only apply in case the PUSCH is a HP PUSCH. In case the HARQ-ACK is HP and the PUSCH is LP, a dynamic indication in DCI for HP HARQ-ACK is needed. |
| Huawei | Support RRC configuration. As an exception, the dynamic enabling/disabling by beta offset = 0 in DCI can be supported if the field is present. |
| Lenovo, Motorola Mobility | Support the proposal. |
| Samsung | Agree  As a side comment, having beta\_offset = 0, or any other non-functioning value, is not acceptable and does not work. What would be the beta\_offset for HP HARQ-ACK if a zero value is indicated (assuming a single beta\_offset field is kept as for LP HARQ-ACK/CSI Type 1/CSI Type 2)? Would the functionality of beta\_offset be disabled and use a semi-static value and why? Also, beta\_offset is an optional feature and can have 0 bit or 1 bit – what is then the meaning of having a beta\_offset when one value (if any) has to be zero? Even for a beta\_offset field with 2-bits, what is the intended benefit of the proposal? To save half-bit (if there was such thing)? In general, it is always preferable to not couple functionalities (especially optional ones) and keep corresponding support separate. |
| TCL | Support the proposal. |
| vivo | Similar comments to the proposal in 2.3.2 for multiplexing enabling/disabling on PUCCH |
| APT | Not support. Dynamic indication to enable/disable the multiplexing is preferred. |

## 2nd round proposals and discussions

Proposal for 2nd round discussion:

For multiplexing a HARQ-ACK into a PUSCH with different priorities in R17, at least support RRC configuration for gNB to enable/disable the multiplexing.

* FFS whether or not to additionally introduce dynamic mechanism, e.g. DCI indication, beta\_offset=0
* FFS: Interaction between the enable/disable mechanism and other multiplexing conditions
* FFS for other types of UCI.

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| Company | Comments |
| Sony | We prefer to use DCI indicator, i.e.:  For multiplexing a HARQ-ACK into a PUSCH with different priorities in R17, at least support RRC configuration for gNB to enable/disable the multiplexing.   * Introduce dynamic mechanism, e.g. DCI indication * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI.   NOTE: Beta-offset = 0 ***DOES NOT*** work for HP UCI + LP PUSCH as this would result in dropping the HP UCI. |
| QC | We support this FL proposal. RRC signaling has to be the baseline because this feature has to work with CG-PUSCH, SPS A/N, etc.  Whether DCI indication is needed can be FFS. In our view, we don’t see strong motivation to introduce DCI indication. Because UL grant has to arrive later than DL grants, when gNB schedule the UL grant, it already knows all the HP and LP A/N payload size, gNB can always schedule more RBs in PUSCH to accommodate UCI multiplexing. Our second concern for dynamic indication is that it increases UE implementation complexity, without strong necessity/motivation to do so. |
| Apple | Support. |
| Sharp | Support |
| Lenovo, Motorola Mobility | Support |
| DOCOMO | We support the proposal. Besides we are fine with the intention of Sony’s update but if we remove “FFS” from the first FFS, we prefer the following. We think Sony got a valid point that beta\_offset=0 does not work for HP UCI+LP PUSCH but non-numerical value may be better than new additional DCI field for simplicity.  For multiplexing a HARQ-ACK into a PUSCH with different priorities in R17, at least support RRC configuration for gNB to enable/disable the multiplexing.   * Introduce dynamic mechanism, e.g. DCI indication, beta\_offset which indicates disabling the multiplexing (i.e. 0 or -1 assuming -1 means no multiplexing) * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions * FFS for other types of UCI. |
| Samsung | Support |
| Quectel | Support DOCOMO’s modifications. DCI indication is supported. |
| InterDigital | We think the DCI indicator is important.  I don’t understand why the UL grant has to arrive later than DL assignment? In case the PUSCH is LP and the HARQ-ACK is HP, the HARQ-ACK is typically indicated later and it is not possible to adjust the scheduling of the PUSCH. The indication to multiplex or not needs to be in the DCI indicating the HP HARQ-ACK for this case. |
| vivo | We think the DCI indicator is important. Support Sony’s modifications. |
| ITRI | Support the proposal. |
| TCL | We support the proposal. |
| Intel | RRC indication is fine for consideration of e.g., CG-PUSCH. For DG-PUSCH, DCI indication is preferred. Similar comment as IDC, the argument on UL grant coming later than DL grant is not clear. |
| Spreadtrum | Support the proposal. |
| CATT | We are fine with the proposal. |
| Nokia/NSB | Not support the proposal.  Similar as commented in 2.3.3, RRC configuration is also needed for enabling/disabling as a baseline. On top of this, gNB should be able to dynamically enable/disable multiplexing HARQ-ACK in PUSCH of different priorities.  Suggest to update the proposal:  “For multiplexing a HARQ-ACK into a PUSCH with different priorities in R17, ~~at least~~ ~~support~~ in addition to RRC configuration, support dynamic indication for gNB to enable/disable the multiplexing.   * FFS ~~whether or not to additionally introduce~~ ~~dynamic~~ mechanism for dynamic enabling/disabling of multiplexing, e.g. ~~DCI indication,~~ beta\_offset=0 * FFS: Interaction between the enable/disable mechanism and other multiplexing conditions   FFS for other types of UCI.” |
| MediaTek | Support the proposal. |
| LG | We support the proposal. |
| ZTE | Support Sony’s modifications. Either OK with FL proposal to compromise. |
| Huawei | Support. The DCI indication can only be applied for dynamic PUCCH/PUSCH, but does not work for the multiplexing enabling/disabling for semi-static PUCCHs/PUSCHs, e.g., SR/SPS HARQ-ACK/CG PUSCH. In contrast, RRC configuration for enabling/disabling is applicable for both dynamic PUCCH and semi-static PUCCH, thus should be considered as the fundamental way to enable/disable. Regarding the progress, we think it is a constructive way to first agree “at least support RRC configuration”, then to further discuss whether and how to support the DCI indication, instead of agreeing both RRC and DCI at one time. |
| Panasonic | We support the proposal. |
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## 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
  + TCL, Intel, Sony, LGE
* Option 2: The LP UCI is compressed/bundled.
  + OPPO, ZTE, MTK, TCL, QC, LGE, Apple

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| Company | Proposals/observations from Tdocs |
| OPPO | ***Proposal 8: 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.*** |
| ZTE | ***Proposal 11:*** *LP UCI compression is slightly preferred in case there is no enough resource left for LP UCI.* |
| MTK | Group-bundling is supported when multiplexing and when the resulted UCI payload is large. |
| TCL | **Proposal 4: For the multiplexing between low priority UCI and high priority PUSCH, if the resource is not sufficient for the multiplexing, considering bundling or partially drop the low priority UCI.** |
| 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 partially dropped if needed.** |
| Qualcomm | ***Proposal 11:* 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 12:* 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.** |
| Sony | **Proposal 9: 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.**  **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.** |
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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, ZTE, China Telecom, TCL, LGE, ITRI
* 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
* Option 3: 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

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 11: 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.*** |
| OPPO | ***Proposal 8: 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.*** |
| ZTE | ***Proposal 12:*** *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.* |
| CATT | ***Observation 1: Reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities will introduce more limitation on scheduling for high priority channels in Rel-17.***  ***Observation 2: If the timeline requirement is allowed to be not met, gNB and UE may have different understandings on whether the multiplexing timeline is satisfied and whether the multiplexing should be performed.***  ***Proposal 2: The time unit of high priority PUCCH is used as the time unit for multiplexing.***  ***Proposal 3: For a low priority PUCCH which goes across multiple time units for multiplexing, the low priority PUCCH joins the multiplexing procedure in each of the overlapping time units for multiplexing from the first overlapping slot, unless the low priority PUCCH was determined to be dropped or multiplexed with other channels.*** |
| MTK | 1. Guard gap timeline of the new multiplexed PUCCH is of the earliest PUCCH. 2. Multiplexing allowed only if the resulted PUCCH is confined within the sub-slot of the HP-PUCCH sub-slot. |
| China Telecom | **Proposal 2: Multiplexing for channels with different priorities is allowed only when the ending symbol of PUCCH or PUSCH resource carrying the multiplexed UCI is no later than the ending symbol of channel carrying HP traffic.** |
| TCL | **Proposal 6: 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.** |
| Qualcomm | ***Proposal 14:* 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 7. d2 for LP CG-PUSCH and HP DG-PUSCH collision resolution   |  |  | | --- | --- | |  | d2 [symbols] | | **0** | **1** | | **1** | **2** | | **2** | **4** | | **3** | **8** |   ***Proposal 15:* 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.**  ***Proposal 16:* Confirm the working assumption made in #104-e to reuse Rel-15 intra-UE PUCCH/PUSCH multiplexing timeline requirements for Rel-17 intra-UE PUCCH/PUSCH multiplexing with different priorities.** |
| 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 #18: For PHY prioritization for the case where low-priority CG-PUSCH collides with high-priority DG-PUSCH, Rel-15 timeline requirements between dynamic grant and configured grant is applied.  Proposal #19: Consider to introduce new timeline or offset in case of PUSCH collision handling with different priority. |
| ITRI | **Proposal 1:**  The UE can multiplex HP UCI in a LP PUSCH only if the processing time of HP UCI is sufficient. Otherwise, the UE should not perform the multiplexing and the LP PUSCH should be dropped.  **Proposal 3:**  To ensure the acknowledgement response validity, a UE should perform the multiplexing procedure only if the latest symbol for multiplexing the HP UCI is not later than the latest symbol of the PUCCH. Otherwise, the UE should not perform the multiplexing. |
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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 9: For more than two overlapping channels, timeline and procedure for multiplexing and prioritization specified in 38.213 can be reused.*** |
| vivo | ***Proposal 17: To avoid the dropping of LP UCI, the overlapping handling order may need be reconsidered.*** |
| CATT | ***Proposal 14: For overlapping between PUCCH and multiple PUSCHs with different priorities, it is proposed that UCI of PUCCH is multiplexed on a PUSCH with different priority only when there is no PUSCH with same priority overlaps with the PUCCH.*** |
| ATP | Proposal 6 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. |
| E/// | [Proposal 1 Prioritize work to stablish early on a common understanding on the overall framework of the expected procedures than detailed solutions.](#_Toc68676138)  [Proposal 2 Investigate the candidate frameworks A1, A2, B1, B2 and their combinations for gain and complexity analysis, starting with B2 and A2-B2.](#_Toc68676139)  [Proposal 3 Consider investigating the complexity of potential features for multiplexing UCI with different priority in PUCCH/PUSCH.](#_Toc68676140)  [Proposal 16 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.](#_Toc68676156)  [Proposal 17 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.](#_Toc68676157) |
| NEC | ***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.*  ***Proposal 7:*** *Further study the order of prioritization or multiplexing for collision cases involving PUSCH and PUCCH with different priorities when simultaneous PUCCH/PUSCH transmission of different priorities over different cells is configured.* |
| Nokia | * **Proposal 3.16: For the scenario where multiplexing high-priority HARQ-ACK bits on a low-priority PUSCH, RAN1 to investigate UL power control aspects to guarantee the required reliability of high-priority HARQ-ACK bits.** * **Proposal 3.17: Multiplexing high-priority SR in low-priority PUSCH is supported. FFS detailed ways of carrying high-priority SR information.** * ***Observation 3.3: 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 3.4: 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 3.5: 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.** |
| Quectel | **Proposal 5**: When multiplexing of a HP HARQ-ACK associated to a later DCI and a LP PUSCH scheduled by an earlier DCI is enabled, two possible solutions could be considered:   * The HP HARQ-ACK is punctured on the LP PUSCH; * The multiplexing is expected to be applied only when certain timeline criterion are met. |
| 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 9: 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.** |
| TCL | **Proposal 7: The scenario of multiplexing more than two overlapping channels should be further studied.** |
| 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 14: 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 15: If a PUCCH overlaps with two PUSCHs, following behaviors can be considered, assuming timeline conditions are met:**   * **If PUCCH is of high priority, PUCCH is multiplexed onto first PUSCH.** * **If first (second) PUSCH is of high (low) priority, UCI from PUCCH is multiplexed onto second PUSCH if the PUCCH is of low priority.**   **Proposal 16: If a PUSCH overlaps with a PUCCH repetition in a slot, multiplex the UCI onto the PUSCH and drop the PUCCH repetition.**   * **FFS whether this is only applicable if PUSCH is of high priority and/or PUCCH is of low priority.** |
| Qualcomm | ***Proposal 1:* Study modulation order and code rate selection for UCI multiplexed on PUSCH based on beta scaled spectrum efficiency of UCI.** |
| Panasonic | **Proposal 1: The collision handling between high-priority SR and low-priority PUSCH should also be supported in Rel.17.** |
| ETRI | **Proposal 10: For HARQ-ACK codebook construction, sub-slot based HARQ-ACK codebooks are concatenated, and can be transmitted for either PUSCH or PUCCH.**  **Proposal 11: DL-DCI for HP UCI which is received after UL-DCI for LP TB may affect the PUSCH mapping.**  **Proposal 12: HP UCI may not be mapped at the second hop of the PUSCH.**  **Proposal 13: Further study how to adjust the power of PUSCH for payload from the other priority.** |
| LGE | Proposal #20: Consider enhanced collision handling between HP PUSCH and LP PUSCH with UCI piggybacking. |
| Sharp | **Proposal 11: For HP HARQ-ACK with or without LP HARQ-ACK on LP PUSCH, details should be further studied on**   * **The timeline restrictions** * **Multiplexing location, e.g. starting/ending symbol** * **Detailed multiplexing methods, etc.** |
| DOCOMO | **Proposal 10:**   * *Discuss PUSCH selection to multiplex PUCCH if the PUCCH overlaps multiple PUSCHs with different priorities.*   **Proposal 11:**   * *Discuss processing order of intra-UE multiplexing with different priorities and cancellation due to dynamic SFI/UL CI/semi-static TDD and SSB.* |
| Leno/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 6:** Specify modified timeline requirements to enable sub-slot based HARQ-ACK multiplexing in PUSCH. * **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. |
| ITRI | **Proposal 2:**  The HP UCI should only multiplexed on a set of LP PUSCH resource even if the LP PUSCH is configured with frequency hoping, and the set of PUSCH resource is selected from the first DMRS symbol of the LP PUSCH that can satisfy the timeline requirement. |
| 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.*** |

# 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.
  + HW, ZTE, vivo, MTK, Nokia, CMCC, Intel, Samsung, Sharp
* 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.
  + Xiaomi

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 13: 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 | ***Proposal 13:*** *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.* |
| 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 | 1. Support PHY prioritization for the case where high-priority DG-PUSCH collides with low-priority CG-PUSCH. 2. 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. |
| E/// | [Proposal 18 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.](#_Toc68676158)  [Proposal 19 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.](#_Toc68676159)  [Proposal 20 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.](#_Toc68676160)  [Proposal 21 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.](#_Toc68676161) |
| 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 12: 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 13:*** ***The case of HP CG-PUSCH overlapping with LP DG-PUSCH should be handled by UE implementation.*** |
| 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.**  **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.** |
| Intel | **Proposal 1: UE is expected to transmit the CG PUSCH and cancel the overlapping DG PUSCH at the latest from the first symbol that is overlapping with the CG PUSCH when collision between HP CG PUSCH and LP DG PUSCH occurs.**   * **Sufficient to capture the above in RAN1 specification.** |
| Samsung | **Proposal 13: 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.** |
| Sharp | **Proposal 12: PHY layer can make the prioritization so that**   * **For collision between HP CG-PUSCH and LP DG PUSCH, the UE is expected to transmit the HP CG-PUSCH and cancel the LP DG-PUSCH at least from the first overlapping symbol.** * **For collision between LP CG-PUSCH and HP DG PUSCH, the UE is expected to transmit the HP DG-PUSCH and cancel the LP CG-PUSCH at least from the first overlapping symbol, but not before Tproc,2+d1 after the scheduling DCI of the HP DG-PUSCH.** |
| DOCOMO | **Proposal 12:**   * *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.* |

## 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.
  + Option 1a:The 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 scheduling the DG PUSCH.
    - ZTE, vivo, MTK, CMCC, Samsung, Sharp
  + Option 1b: 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.
    - HW,
* Option 2: The Rel-16 handling of the scenarios where a dynamically scheduled high-priority channel overlaps with a low-priority channel is adopted.
  + Nokia, Xiaomi
* Option 3: 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 4: Per UE capability.
  + Intel

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Proposal 14: 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 CG PUSCH by the first overlapping symbol at the latest.***   * ***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.*** |
| ZTE | ***Proposal 14:*** *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.* |
| 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 | 1. 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. |
| 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.** |
| CMCC | **Proposal 13: 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 14:*** ***For LP CG-PUSCH overlaps with HP DG-PUSCH, related cancelation behaviour for LP CG-PUSCH defined in R16 can be reused.*** |
| 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.** |
| Samsung | **Proposal 14: 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.** |
| Sharp | **Proposal 12: PHY layer can make the prioritization so that**   * **For collision between HP CG-PUSCH and LP DG PUSCH, the UE is expected to transmit the HP CG-PUSCH and cancel the LP DG-PUSCH at least from the first overlapping symbol.** * **For collision between LP CG-PUSCH and HP DG PUSCH, the UE is expected to transmit the HP DG-PUSCH and cancel the LP CG-PUSCH at least from the first overlapping symbol, but not before Tproc,2+d1 after the scheduling DCI of the HP DG-PUSCH.** |
| DOCOMO | **Proposal 12:**   * *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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# 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.*

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*

## How to trigger this function?

## Inputs from Tdocs

Support dynamic indication?

* No
  + CATT, Nokia, QC
* Yes:
  + E///

Separate configurations

* 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 |
| CATT | ***Proposal 15: Dynamic indication of simultaneous PUCCH/PUSCH transmission is not supported.*** |
| MTK | 1. The UE is to be configured separately for inter-band and intra-band simultaneous PUCCH/PUSCH transmissions. 2. Per UE with the capability of inter-band CA, simultaneous PUCCH/PUSCH transmission of the same PHY priority over different cells can be RRC configured within the same PUCCH group. 3. Simultaneous PUCCH/PUSCH transmissions is enabled based on specific conditions. E.g. LP-PUCCH carrying HARQ feedback. |
| E/// | [Proposal 5 When simultaneous PUCCH/PUSCH transmissions is enabled by RRC configuration, simultaneous PUCCH/PUSCH transmissions can be dynamically disabled.](#_Toc68676142)  Proposal 6 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. |
| Nokia | * **Proposal 4.5: 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).** |
| Qualcomm | ***Proposal 19:* 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.** |
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## Use cases for simultaneous PUCCH/PUSCH transmission

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| Company | Proposals/observations from Tdocs |
| Nokia | * **Proposal 4.1: RAN1 to clarify the intention of the support of simultaneous PUCCH / PUSCH, namely what to improve in terms of e.g. LP channel or information dropping, latency, reliability, efficiency or the like.** * ***Observation 4.1: For the scenario of only having PUCCH for a certain priority, the support of simultaneous PUCCH/PUSCH transmission of different PHY priorities on different serving cells at least for inter-band CA requires changes to the overlapping determination and related cancelation behaviour of Rel-16 PHY prioritization operation.*** * ***Observation 4.2: When considering more than two overlapping channels, the support of simultaneous PUCCH/PUSCH transmissions of different PHY priorities on different serving cells at least for inter-band CA to reduce the LP channel dropping in Rel-17 requires changes to all logical steps of the Rel-16 PHY prioritization operation, namely (i) the order of LP multiplexing and PHY prioritization, (ii) the order of PHY prioritization and HP UL multiplexing, (ii) the overlapping determination and (iv) the related cancelation behaviour of Rel-16 PHY prioritization operation.*** * ***Observation 4.3: The support of simultaneous PUSCH/PUCCH of the same PHY priority will increase low-priority information and channel dropping when taking the PHY prioritization into account.*** * **Proposal 4.2: RAN1 to discuss and clarify, for which cases simultaneous PUCCH / PUSCH operation of different priorities should be supported with respect to the required changes to the PHY prioritization operation / behavior, including at least:**    + **Are changes to the processing order of LP multiplexing and PHY prioritization in scope?**   + **Are changes to the processing order of PHY prioritization and HP UL channel multiplexing in scope?**   + **Is the intention to support case-specific optimized solutions to enable simultaneous PUSCH/PUCCH of different PHY priorities for all possible overlapping cases or instead a generic enhancement of the PHY prioritization framework / procedure (with limitations for some cases)?** |

## Support simultaneous PUCCH/PUSCH transmission of same PHY priority?

#### Inputs from Tdocs

* Yes:
  + CATT, E///
* No:
* Nokia

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| Company | Proposals/observations from Tdocs |
| CATT | ***Proposal 16: Simultaneous PUCCH/PUSCH transmission of same PHY priority over different cells for inter-band CA can be supported.*** |
| E/// | [Proposal 4 Support simultaneous PUCCH/PUSCH transmission of same PHY priorities over different cells can be RRC configured within the same PUCCH group](#_Toc68676141) |
| Nokia | * **Proposal 4.3: 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.** |
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## Support simultaneous PUSCH/PUCCH transmission for intra-band CA or not?

#### Inputs from Tdocs

* Support with conditions
  + CATT, MTK (for some cases), Intel (when their durations are aligned), Apple (introducing PTRS for PUCCH to handle phase discontinuity problem), 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 |
| CATT | ***Proposal 17: Simultaneous PUCCH/PUSCH transmission for intra-band CA can be supported.*** |
| MTK | 1. Support simultaneous PUCCH/PUSCH transmissions on different cells for intra-band CA for the same numerology both with aligned and non-aligned channel case. 2. 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.  1. The UE is to be configured separately for inter-band and intra-band simultaneous PUCCH/PUSCH transmissions. |
| Nokia | * **Proposal 4.4: For intra-band CA, simultaneous transmission of PUCCH and PUSCH on different cells is not supported.** |
| Intel | **Observation 5: 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.** |
| Apple | **Proposal 10-1: Simultaneous PUCCH/PUSCH transmission for intra-band CA is not supported if phase discontinuity problem cannot be addressed.**  **Proposal 10-2: consider the feasibility of introducing PTRS for PUCCH to handle phase discontinuity problem in simultaneous PUCCH/PUSCH transmissions for intra-band CA.** |
| Samsung | **Observation 4: 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.**  **Proposal 11: Send an LS to RAN4 to inquire about the feasibility/MPR for simultaneous PUCCH and PUSCH transmissions on a same cell.**  **Proposal 12: 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.** |
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## Support simultaneous PUSCH/PUCCH transmission on a same cell?

#### Inputs from Tdocs

* No:
  + Apple, DCM

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| Company | Proposals/observations from Tdocs |
| Apple | **Proposal 10-3: Simultaneous PUCCH/PUSCH transmission on the same CC is not supported.** |
| DOCOMO | **Proposal 13:**   * *Not to introduce the simultaneous PUCCH and PUSCH transmission for same priority case.* |
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## Prioritization rules

## Inputs from Tdocs

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| Company | Proposals/observations from Tdocs |
| Huawei | ***Observation 2: If simultaneous PUCCH/PUSCH transmission of different PHY priorities over different cells is configured, the prioritization of LP PUCCH/PUSCH can be performed as follows.***   * ***Step 1: perform the multiplexing of LP PUCCH(s)/PUSCH assuming no overlapping HP UL channels and determine the final LP PUCCH/PUSCH;*** * ***Step 2: judge whether the final LP PUCCH/PUSCH is overlapping with any HP UL channels before and/or after multiplexing of HP UL channels, and if an overlapping happens on the same serving cell or cells within the same band, the LP PUCCH/PUSCH is dropped.*** |
| vivo | ***Proposal 18: It should be clarified whether and how the two mechanisms i.e., simultaneous PUCCH/PUSCH of different priorities and multiplexing of different priorities can be configured to work together.*** |
| Intel | **Proposal 17: 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.** |
| Apple | **Proposal 9-1: Clarify the Rel-16 UE behavior concerning DG/CG transmission.** |
| Qualcomm | ***Proposal 20:* 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 a component carrier.** |
| 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.** |
| DOCOMO | **Proposal 14:**   * *Support PHR for simultaneous PUCCH and PUSCH transmission on different carriers.*   **Proposal 15:**   * *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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