3GPP TSG RAN WG1 #108-e R1-220xxxx

e-Meeting, February 21 – March 3, 2022

Source: Moderator (OPPO)

Title: Summary#1 of email thread [108-e-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#108 are summarized.

[108-e-R17-IIoT-URLLC-04] Email discussion on intra-UE multiplexing/prioritization – Jia (OPPO)

* Focus on PHY prioritization of overlapping DG-PUSCH/CG-PUSCH and remaining details on intra-UE multiplexing of UCI of different priorities on PUCCH and PUSCH (except multiplexing/overlapping resolution procedure)
* 1st check point: February 25
* Final check point: March 3

# 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 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?*

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 is more than 2, support separate coding for the two HARQ-ACKs.*

* *FFS for HP HARQ-ACK or LP HARQ-ACK of 1-2 bit(s).*
* *(working assumption) Drop CSI (including part 1 and part2, if exist) if CSI would multiplex on a PUCCH which has HP A/N.*
	+ *FFS Strive to let HP A/N reuse the encoder, rate matching equation, and RE mapping rules in Rel-15 for A/N+CSI-1.*
	+ *FFS Strive to let LP A/N reuse the encoder, rate matching equation, and mapping rules in Rel-15 for CSI-2.*

Agreement:

*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,*

* *For HP HARQ-ACK or LP HARQ-ACK of 1-2 bit(s), support separate coding. Down-select from the two options:*
	+ *Option 1: Reuse R15 TS 38.212 Clause 5.3.3.1 for 1-bit. Reuse R15 TS 38.212 Clause 5.3.3.2 for 2-bit.*
	+ *Option 2: Reuse R15 TS 38.212 Clause 5.3.3.3, i.e., padding to 3 bits and using RM coding.*
* *For HP HARQ-ACK or LP HARQ-ACK >2 bit(s), HP HARQ-ACK and LP HARQ-ACK are separately encoded according to R15 TS 38.212 Clause 5.3.3.3 or Clause 5.3.1.*
* *FFS rate matching equation and RE mapping rules for PF2/3/4. Rel-15 is baseline if available.*

Agreement:

*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 High priority.*

* *Rel-15 design (for PF0 and PF1) is baseline.*
* *Note: Qualcomm has strong concern on above scheme. The scheme cannot provide unequal error protection between the HP bit and LP bit hence could suffer from performance degradation for the HP bit. Qualcomm accepts the scheme for the sake of progress in RAN 1 with the concern on the performance reserved.*

Agreement

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

* *HP A/N reuses rate matching equation, and RE mapping rules in Rel-15 for A/N+CSI-1.*
* *LP A/N reuses rate matching equation, and RE mapping rules in Rel-15 for CSI-2.*

*Above applies at least for PUCCH format 3 and 4.*

Agreement

*For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17, an additional maxCodeRate for LP HARQ-ACK can be configured in the second PUCCH-Config per PUCCH format.*

Agreement

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

* *PUCCH resource set determination is based on: UCI payload size = the number of HP UCI bits + the number of LP UCI bits.*
* *FFS PRB number determination for HP A/N and LP A/N, e.g. based on their coding rates.*
* *FFS the impact to the number of LP UCI bits due to missed DCI and potential solutions*
* *Note: the number of LP UCI bits in the above agreement does may not necessarily mean the actual number of LP UCI bits until the second FFS is resolved*

Agreement

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

* *Use a PUCCH resource in the second PUCCH-Config (the PUCCH-config containing the PUCCH resource of the HP HARQ-ACK).*

Agreement

*For determining the PUCCH resource to carry the multiplexed high-priority and low-priority HARQ-ACKs,*

* *The number of RBs for multiplexing HP HARQ-ACK and LP HARQ-ACK on a PUCCH format 3 is determined as following:*
	+ - *If* $\left(\frac{O\_{HP\\_UCI}+O\_{CRC, HP\\_UCI}}{r\_{HP\\_UCI}∙Q\_{m}}+\frac{O\_{LP\\_UCI}+O\_{CRC, LP\\_UCI}}{r\_{LP\\_UCI}∙Q\_{m}}\right)$$\leq M\_{RB}^{PUCCH}∙N\_{sc, ctrl}^{RB}∙N\_{symb-UCI}^{PUCCH}$*, the minimum number of RBs is determined as the number of* $M\_{RB, min}^{PUCCH}$*, satisfying* $\left(\frac{O\_{HP\\_UCI}+O\_{CRC, HP\\_UCI}}{r\_{HP\\_UCI}∙Q\_{m}}+\frac{O\_{LP\\_UCI}+O\_{CRC, LP\\_UCI}}{r\_{LP\\_UCI}∙Q\_{m}}\right)\leq M\_{RB,min}^{PUCCH}∙N\_{sc, ctrl}^{RB}∙N\_{symb-UCI}^{PUCCH}$ *and* $\left(\frac{O\_{HP\\_UCI}+O\_{CRC, HP\\_UCI}}{r\_{HP\\_UCI}∙Q\_{m}}+\frac{O\_{LP\\_UCI}+O\_{CRC, LP\\_UCI}}{r\_{LP\\_UCI}∙Q\_{m}}\right)>\left(M\_{RB,min}^{PUCCH}-1\right)∙N\_{sc, ctrl}^{RB}∙N\_{symb-UCI}^{PUCCH}.$
			* *Note:* $r\_{HP\\_UCI}∙r\_{LP\\_UCI}∙Q\_{m}$ *is multiplied at both sides to avoid mismatch between gNB and UE due to floating point operation. Editor to capture as suggested.*
		- *Otherwise,*
			* *Alt1: the number of RBs is* $M\_{RB}^{PUCCH}$*. FFS: Whether/How LP HARQ-ACK is dropped.*
			* *Alt2: the number of RBs is determined by HP ACK payload size. LP HARQ-ACK is fully dropped.*
			* *Other alternatives are not precluded.*
		- *r\_HP\_UCI is maxCodeRate configured for HP bits and r\_LP\_UCI is maxCodeRate configured for LP bits in the second PUCCH-Config (the PUCCH-config containing the PUCCH resource of the HP HARQ-ACK).*
			* *FFS whether more than one maxCodeRate can be configured for one priority.*
		- *If* $M\_{RB, min}^{PUCCH}$ *is not equal to  according to [4, TS 38.211],* $M\_{RB, min}^{PUCCH}$ *is increased to the nearest allowed value of nrofPRBs for PUCCH-format3 provided by the second PUCCH-Config**[12, TS 38.331].*
		- *HP coded bits and LP coded bits are not transmitted using the same RE(s)*
	+ *FFS for PUCCH format 2.*

Agreement

*For determining the PUCCH resource to carry the multiplexed high-priority and low-priority HARQ-ACKs, if* $\left(\frac{O\_{HP\\_UCI}+O\_{CRC, HP\\_UCI}}{r\_{HP\\_UCI}∙Q\_{m}}+\frac{O\_{LP\\_UCI}+O\_{CRC, LP\\_UCI}}{r\_{LP\\_UCI}∙Q\_{m}}\right)$$>M\_{RB}^{PUCCH}∙N\_{sc, ctrl}^{RB}∙N\_{symb-UCI}^{PUCCH}$

* *The number of RBs is* $M\_{RB}^{PUCCH}$*. Then follow Rel-15 procedure, i.e., LP HARQ-ACK is mapped to the rest REs after HP HARQ-ACK.*

Agreement

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

* *At least for PUCCH format 3/4, use the HP UCI bit number and HP RE number for ∆TF,b,f,c(i)*$∆\_{TF, b, f,c}\left(i\right) $*formula selection and calculation*
* *For PUCCH format 1, use the total UCI bit number for ∆TF,b,f,c(i) calculation.*
* *FFS for PUCCH format 2.*

Agreement

Support multiplexing of high-priority HARQ-ACK and low-priority HARQ-ACK on PUCCH Format 2.

* Extend legacy agreements on PRB number determination for Rel-17 (RAN1#106bis-e and RAN1#107-e) to cover PUCCH Format 2.
* Use the HP UCI bit number and HP RE number for ∆TF,b,f,c(i) formula selection and calculation (as for PUCCH formats 3 & 4).
* Concatenate the coded HP HARQ-ACK bits and the coded LP HARQ-ACK bits sequentially and apply the procedures described in R15 TS 38.211 to the concatenated coded HARQ-ACK bit sequence.

**Agreement**

When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF2/3/4:

* For positive SR, transmit SR on the SR PUCCH resource and drop HARQ-ACK.
* For negative SR, transmit HARQ-ACK only on the HARQ-ACK PUCCH resource.

Note: It was agreed to support multiplexing a LP HARQ-ACK and a HP SR into a PUCCH for some HARQ-ACK/SR PF combinations in Rel-17.

**Agreement**

When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 2/3/4 overlaps with a PUCCH carrying LP HARQ-ACK, information bits for K HP SRs are appended to HP HARQ-ACK bits, and treat them as HP UCI, where K (K≥1) PUCCHs semi-statically configured for K HP SRs overlap with the original PUCCH carrying the HP HARQ-ACK.

* The number of HP UCI bits is $O\_{UCI}=O\_{ACK}+\left⌈log\_{2}\left(K+1\right)\right⌉$, same as Rel-15;
	+ FFS: PF0, PF1
* Reuse other procedures for multiplexing of LP HARQ-ACK and HP HARQ-ACK on PUCCH resource with PF 2/3/4, i.e. separate coding, PRB determination, rate matching and power control.
* If the HP HARQ-ACK is a dynamic HARQ-ACK, a PUCCH resource indicated by PRI is used for multiplexing.
* If the HP HARQ-ACK is a SPS HARQ-ACK, a PUCCH resource determined from the PUCCH resource(s) provided by sps-PUCCH-AN-List is used for multiplexing.

**Agreement**

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, for HP HARQ-ACK or LP HARQ-ACK of 1-2 bit(s), support separate coding

* Option 1: Reuse R15 TS 38.212 Clause 5.3.3.1 for 1-bit. Reuse R15 TS 38.212 Clause 5.3.3.2 for 2-bit. Apply the Rel-15 placeholder bit handling procedure for PUSCH together with Rel-15 PUCCH scrambling sequence.

## Remaining issues on coding and resource determination

## Inputs from Tdocs

**Issue 2.2-1: Bit mapping for 1bit HP/LP HARQ-ACK**

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, the order of the multiplexed two bits could be [high-priority HARQ-ACK bit, low-priority HARQ-ACK bit].

* + HW, Nokia, CTC, DCM, Intel, Samsung

**Issue 2.2-2: CSI dropping or not:**

* + Option 1: Confirm WA: Drop CSI (including part 1 and part2, if exist) if CSI would multiplex on a PUCCH which has HP A/N.
		- Nokia
	+ Option 2: Drop CSI part 2 if CSI would multiplex on a PUCCH which has HP A/N.
		- DCM

**Issue 2.2-3: The problem of ambiguity on LP HARQ-ACK existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection:**

* **Proposal from last meeting discussion:**

For the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection, a new T-DAI field can be RRC configured:

* For multiplexing HP HARQ-ACK and Type-2/Type-1 LP HARQ-ACK codebook,
	+ A T-DAI field in a DL DCI format associated with HP HARQ-ACK to indicate the T-DAI of LP HARQ-ACK.
	+ At most 2 bits are added to the DL DCI format associated with HP HARQ-ACK for the T-DAI of LP HARQ-ACK, compared to Rel-16.
* For multiplexing a LP Type-2/Type-1 HARQ-ACK codebook in a HP PUSCH,
	+ A T-DAI field in a UL DCI format scheduling the HP PUSCH to indicate the T-DAI of LP HARQ-ACK.
	+ At most 2 bits are added to the UL DCI format scheduling the HP PUSCH for the T-DAI of LP HARQ-ACK, compared to Rel-16.
* Note: If the new T-DAI field is not RRC configured, the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection is handled by gNB implementation.
* FFS whether/how to multiplex LP HARQ-ACK sub-codebook for CBG-based PDSCH on HP PUCCH or HP PUSCH with single new T-DAI field.
* Support: Huawei/Hisi, Nokia/NSB, ZTE, CATT, DCM, IDC, Intel, NEC, Samsung, LG
* Not support: vivo, Ericsson, OPPO

**HW proposal:**

* Whether/how to handle the LP HARQ-ACK ambiguity in case of overlapping with HP SPS HARQ-ACK is up to gNB implementation.
* **Other options:**
	+ Option 1: Configure a dedicated PUCCH resource for HP and LP HARQ-ACK in the second PUCCH-Config.
		- Pana
	+ Option 2: PRI+x in the HP DCI is used to implicitly determine an extended PUCCH resource
		- ZTE
	+ Option 3a: The LP type 2 codebook size is quantized/rounded up to a nearest reference size. FFS reference size granularity.
		- QC
	+ Option 3b: Configuration of semi-static size reservation for LP HARQ-ACK payload is provided by RRC. LP HARQ-ACK semi-static size reservation is used instead of determined LP HARQ-ACK codebook size when selecting the PUCCH resource set.
		- LG
	+ Option 5:
		- for 1-bit LP HARQ-ACK and 1-bit HP HARQ-ACK multiplexed in PF0, CS=0, 3, 6, 9 is mapped to (HP HARQ-ACK, LP HARQ-ACK)=(NACK, NACK), (NACK, ACK), (ACK, NACK), (ACK,ACK);
		- for 1-bit LP HARQ-ACK and 1-bit HP HARQ-ACK multiplexed in PF1, (HP HARQ-ACK, LP HARQ-ACK) is QPSK modulated using 
		- CTC

|  |
| --- |
| Resource determination for multiplexing between HARQ-ACKs with different priorities |
|  | Arguments | Counter arguments |
| Option 1 | 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. |  |

**Issue 2.2-4: Overlapping handling for Type 3 codebook HARQ-ACK**

**HW proposal:**

UE does not expect the overlapping between HP PUCCH/PUSCH and LP HARQ-ACK subject to Type 3 codebook/enh. Type 3 codebook/one shot retransmission.

**Issue 2.2-5: Multiplexing for SPS HARQ-ACK**

**Status in running specification:**

UE determines the PUCCH resource from the second *sps-PUCCH-AN-List* using $O\_{UCI}=O\_{ACK,0}+O\_{ACK,1}$

**Samsung proposal:**

A separate RRC parameter configures enabling/disabling multiplexing of LP HARQ-ACK and HP SPS HARQ-ACK.

**Issue 2.2-6: PRI selection for HP A/N and LP A/N multiplexing**

**QC proposal:**

For multiplexing HP HARQ-ACKs and LP HARQ-ACKs, the PRI in the lastly received DCI (if exist), which schedules a HP HARQ-ACK involved in the multiplexing, is used to select the PUCCH resource to transmit the multiplexed payload.

**LG proposal:**

Adopt the following to determine a PUCCH resource in the HP PUCCH resource set selected based on total UCI payload size.

* In case when at least one HP DL DCI is received by UE, the HP PUCCH resource corresponding to the PRI indicated in the last HP DCI is selected.
* In case when LP DL DCI is only received by the UE, the HP PUCCH resource corresponding to the PRI indicated in the last LP DCI is selected.

**Issue 2.2-7: Details on transmission power**

**Apple proposal:**

For PUCCH formats 2/3/4, the delta factor $Δ\_{TF,b,f,c}\left(i\right)$ is determined from UCI part 1:

* The number of resource elements for UCI part 1 $N\_{RE-part1}(i)=\frac{E\_{UCI-part1}}{E\_{tot}}N\_{RE}(i), $ where $ E\_{UCI-part1}$ is the number of coded bits for UCI part 1
* If $\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}$ is smaller or equal to 11,
	+ $Δ\_{TF,b,f,c,part1}\left(i\right)=10⋅log\_{10}(K\_{1}⋅\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}\right)/N\_{RE-part1}\left(i\right))$
	+ If a HARQ-ACK codebook with $O\_{UCI-part1,n^{'} }$ bits is included in UCI part 1,  is used instead of $O\_{UCI-part1,n^{'} }$ for the HARQ-ACK codebook:
		- $Δ\_{TF,b,f,c,part1}\left(i\right)=10⋅log\_{10}(K\_{1}⋅\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}-O\_{UCI-part1,n^{'} }+n\_{HARQ-ACK}(i)\right)/N\_{RE-part1}\left(i\right))$
	+ If more than one HARQ-ACK codebooks are included in UCI part 1 (e.g. one due to SPS HARQ deferral, another for HARQ feedback for dynamic grant PDSCH(s)), then replacement of the number of HARQ-ACK codebook size by the associated $n\_{HARQ-ACK}$ can be applied to each HARQ-ACK codebook.
* otherwise
	+ $Δ\_{TF,b,f,c,part1}\left(i\right)=10log\_{10}(2^{K\_{2}⋅BPRE\left(i\right)}-1) $where
		-  and
		- $\begin{matrix}BPRE\left(i\right)=&&\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}+O\_{CRC,UCI-part1}\right)&/N\_{RE-part1\left(i\right)}&\end{matrix}$
* And $Δ\_{TF,b,f,c}\left(i\right)$ = $Δ\_{TF,b,f,c,part1}\left(i\right)$ is applied to both UCI parts.

**Additional coding rate configuration**

* Support maxCodeRateAdd parameter for the maximum coding rate of HP HARQ-ACK r1. In case the number of PRBs $M\_{RB,min}^{PUCCH}$ with r1 = maxCodeRateAdd is equal to the one obtained with r1=maxCodeRate, r1 is set to maxCodeRateAdd. Otherwise, r1 is set to maxCodeRate.
	+ IDC

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| Company | Proposals/observations from Tdocs |
| HW | ***Proposal 9: For the multiplexed 1 bit HP HARQ-ACK and 1 bit LP HARQ-ACK on PUCCH format 0/1, the HP HARQ-ACK bit should be mapped in prior to the LP HARQ-ACK bit.******Proposal 10: Additional LP T-DAI indication can be introduced in HP DL DCI to resolve the issue of ambiguous LP HARQ-ACK payload size in case of collision with HP HARQ-ACK.**** ***2 bits LP T-DAI for Type 2 HARQ-ACK codebook to indicate the LP HARQ-ACK payload size.***
* ***1 bit LP T-DAI for Type 1 HARQ-ACK codebook to indicate the presence of LP HARQ-ACK.***
	+ ***The UE should not transmit LP Type 1 HARQ-ACK on HP PUCCH in case of the LP T-DAI = 0 regardless of the fallback cases of receiving only a SPS release of fallback DCI with C-DAI=1 or only a PDSCH scheduled by fallback DCI on PCell with C-DAI=1.***

***Proposal 11: UE does not expect the overlapping between HP PUCCH and LP HARQ-ACK subject to Type 3 codebook/enh. Type 3 codebook/one shot retransmission.******Proposal 12: Whether/how to handle the LP HARQ-ACK ambiguity in case of overlapping with HP SPS HARQ-ACK is up to gNB implementation.******Observation: If LP Type 2 HARQ-ACK codebook includes two HARQ-ACK sub-codebooks separately for TB and CBG, then adding two additional T-DAI fields (i.e. 4bits) in HP DCI for two LP HARQ-ACK sub-codebooks will lead to too large HP DCI overhead.******Proposal 13: For multiplexing of HP HARQ-ACK and LP HARQ-ACK with two LP sub-codebooks, the one additional LP T-DAI field (i.e. 2bits) in HP DCI should be applied to both the first LP TB-based HARQ-ACK sub-codebook and the second LP CBG-based HARQ-ACK sub-codebook.*** |
| E/// | [Proposal 5 Do not introduce an additional LP DAI in DCI formats scheduling PUSCH and PDSCH.](#_Toc95752009) |
| Nokia | * **Proposal 3.1: 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, the order of the multiplexed two bits could be [high-priority HARQ-ACK bit, low-priority HARQ-ACK bit].**
* **Proposal 3.2: Confirm the RAN1#104bis-e meeting’s Working Assumption to not support multiplexing of CSI (including part 1 and part 2, if any) and high-priority HARQ-ACK on PUCCH and thus to drop the CSI and prioritize the high-priority HARQ-ACK.**
* ***Observation 3.1: Errors in low-priority HARQ-ACK codebook size determination e.g. due to missed DCI may cause selection of different PUCCH resource set or use of smaller number of PRBs for the multiplexed high-priority and low-priority HARQ-ACKs feedback than what gNB would expect.***

* **Proposal 3.3: For the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI misdetection, a new T-DAI field can be RRC configured:**
	+ **For multiplexing HP HARQ-ACK and Type-2/Type-1 LP HARQ-ACK codebook,**
		- **A T-DAI field in a DL DCI format associated with HP HARQ-ACK to indicate the T-DAI of LP HARQ-ACK.**
		- **At most 2 bits are added to the DL DCI format associated with HP HARQ-ACK for the T-DAI of LP HARQ-ACK, compared to Rel-16.**
	+ **For multiplexing a LP Type-2/Type-1 HARQ-ACK codebook in a HP PUSCH,**
		- **A T-DAI field in a UL DCI format scheduling the HP PUSCH to indicate the T-DAI of LP HARQ-ACK.**
		- **At most 2 bits are added to the UL DCI format scheduling the HP PUSCH for the T-DAI of LP HARQ-ACK, compared to Rel-16.**
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| vivo | ***Proposal 6: It is up to gNB implementation to resolve the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection.*** |
| ZTE | ***Proposal 10:*** *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 the payload size is more than 2 but less than 12, RM code is performed.*
* *If the payload is more than 11 bits, Polar coding is performed.*

***Proposal 11:*** *Modify the agreement in RAN1#106-e in RED:**For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUCCH in R17* ***in case of the total number of LP and HP HARQ-ACK bits >2****,* * *HP A/N reuses rate matching equation, and RE mapping rules in Rel-15 for A/N+CSI-1.*
* *LP A/N reuses rate matching equation, and RE mapping rules in Rel-15 for CSI-2.*

*Above applies at least for PUCCH format 3 and 4.****Proposal 12****: 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 same PUCCH set in the PUCCH-config with high priority for the multiplexed UCI.** *x is predefined, e.g., x=1.*
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| OPPO | ***Proposal 7: Additional enhancement to avoid ambiguity caused by LP DCI missing is not supported.*** |
| CATT | ***Proposal 7: To avoid the impact on HP PUCCH/PUSCH due to missing DCIs corresponding to LP HARQ-ACK codebook, it is proposed to indicate the number of LP HARQ-ACK bits by a new T-DAI field in DCI corresponding to HP PUCCH/PUSCH.*** |
| Pana | Proposal 3: Either of following option is taken.* **Option 1: Configuration of semi-static size reservation for LP HARQ-ACK payload is provided by RRC. LP HARQ-ACK semi-static size reservation is used instead of determined LP HARQ-ACK codebook size when selecting the PUCCH resource set and PRB number determination.**
* **Option 2: Total DAI field in a DL DCI format associated with HP HARQ-ACK to indicate the total DAI of LP HARQ-ACK.**
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| CTC | **Proposal 1: For the scenario where a PUCCH carrying HP HARQ-ACK overlaps with another PUCCH carrying LP HARQ-ACK and the total payload size is 2 bits, the order of the multiplexed two bits could be [HP HARQ-ACK bit, LP HARQ-ACK bit].****Proposal 2: For the problem of ambiguity on LP HARQ-ACK existence,*** **for 1-bit LP HARQ-ACK and 1-bit HP HARQ-ACK multiplexed in PF0, CS=0, 3, 6, 9 is mapped to (HP HARQ-ACK, LP HARQ-ACK)=(NACK, NACK), (NACK, ACK), (ACK, NACK), (ACK,ACK);**
* for 1-bit LP HARQ-ACK and 1-bit HP HARQ-ACK multiplexed in PF1, (HP HARQ-ACK, LP HARQ-ACK) is QPSK modulated using
 |
| DCM | **Proposal 1:*** *The bit order of HP HARQ-ACK and LP HARQ-ACK can be [HP HARQ-ACK bit, LP HARQ-ACK bit] in case the total number of LP and HP HARQ-ACK bits is 2.*

**Proposal 2:*** *CSI part 2 is dropped if CSI would be multiplexed on a PUCCH which has HARQ-ACK information in case the total number of LP and HP HARQ-ACK bits is more than 2.*

**Proposal 3:***For the problem of ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI miss-detection, a T-DAI field is introduced in a DL DCI format and a UL DCI format to indicate the T-DAI of LP HARQ-ACK for multiplexing on PUCCH and PUSCH, respectively* |
| IDC | ***Proposal 4: Support* maxCodeRateAdd *parameter for the maximum coding rate of HP HARQ-ACK r1. In case the number of PRBs*** $M\_{RB,min}^{PUCCH}$***with r1 =* maxCodeRateAdd *is equal to the one obtained with r1=*maxCodeRate*, r1 is set to* maxCodeRateAdd*. Otherwise, r1 is set to* maxCodeRate*.******Proposal 5: DCI indicating HP HARQ-ACK includes an indication of the DAI of LP HARQ-ACK.******Proposal 6: RRC can configure 2-bits field combining priority indication and DAI of LP HARQ-ACK.*** |
| Intel | **Proposal 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, the order of the multiplexed two bits is [high-priority HARQ-ACK bit, low-priority HARQ-ACK bit].****Proposal 8: For multiplexing a HP HARQ-ACK and LP HARQ-ACK into a PUCCH or PUSCH, additional T-DAI for LP HARQ-ACK can be indicated by the DCI scheduling HP HARQ-ACK/HP PUSCH for type-2 HARQ-ACK codebook.** **Proposal 8: For multiplexing a HP HARQ-ACK and LP HARQ-ACK into a PUCCH or PUSCH, additional T-DAI for LP HARQ-ACK can be indicated by the DCI scheduling HP HARQ-ACK/HP PUSCH for type-2 HARQ-ACK codebook.**  |
| Apple | **Observation 3-1: in Rel-16, for PRB number adjustment/interlace number adjustment, the configured PRB number of the selected PUCCH resource (if it is at PF2 or PF3),** $O\_{UCI}$**,** $O\_{CRC}$**, maxCodeRate according to the PUCCH format of the selected PUCCH resource,** $O\_{UCI}$**,** $O\_{CRC}$**, maxCodeRate according to the PUCCH format of the selected PUCCH resource are used as inputs, and the same coding rate is used for two CSI parts.****Proposal 3-1: If a UE is provided a first interlace of** $M\_{Interlace,0}^{PUCCH}$ **PRBs by interlace0 in InterlaceAllocation, the UE has HARQ-ACK, SR and wideband or sub-band CSI reports to transmit, and the UE determines a PUCCH resource with PUCCH format 2, or the UE has HARQ-ACK, SR and wideband CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 3, or the UE has HARQ-ACK, SR and sub-band CSI reports to transmit, and the UE determines a PUCCH resource with PUCCH format 3, where****- the UE determines the PUCCH resource using the PUCCH resource indicator field in a last of a number of DCI formats with a value of a PDSCH-to-HARQ\_feedback timing indicator field indicating a same slot for the PUCCH transmission, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and after the UE determines the PUCCH resource set****- if**$\left(\sum\_{n=1}^{N\_{UCI-part2}^{total}}O\_{UCI-part2,n}+O\_{CRC,UCI-part2}\right)/\left(Q\_{m}⋅r\_{2}\right)+⌈\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}O\_{UCI-part1,n}+O\_{CRC,UCI-part1}\right)/\left(Q\_{m}⋅r\_{1}\right)⌉\leq M\_{Interlace,0}^{PUCCH}⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}$**,****the UE transmits the HARQ-ACK, SR, and CSI reports bits in a PUCCH over the first interlace****- else, if the UE is provided a second interlace of** $M\_{Interlace,1}^{PUCCH}$ **PRBs by interlace1 and if**$\left(\sum\_{n=1}^{N\_{UCI-part2}^{total}}O\_{UCI-part2,n}+O\_{CRC,UCI-part2}\right)/\left(Q\_{m}⋅r\_{2}\right)+⌈\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}O\_{UCI-part1,n}+O\_{CRC,UCI-part1}\right)/\left(Q\_{m}⋅r\_{1}\right)⌉\leq \left(M\_{Interlace,0}^{PUCCH}+M\_{Interlace,1}^{PUCCH}\right)⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}$**,****the UE transmits the HARQ-ACK, SR, and CSI reports bits in a PUCCH over both the first and second interlaces****- else, the UCI omission procedure is same as the corresponding one when the UE is provided PUCCH-ResourceSet by replacing** $M\_{RB}^{PUCCH}$ **with** $M\_{Interlace,0}^{PUCCH}$**, or, if the UE is provided interlace1, by** $M\_{Interlace,0}^{PUCCH}+M\_{Interlace,1}^{PUCCH}$**.****Proposal 4-1: leverage the Rel-15 design, LP HARQ-ACK is mapped to UCI Part II in separate encoding, adopt the UCI mapping in Figures 4-3a/4-3b.****Proposal 6-1: For PUCCH formats 2/3/4, the delta factor** $Δ\_{TF,b,f,c}\left(i\right)$ **is determined from UCI part 1:** * **The number of resource elements for UCI part 1** $N\_{RE-part1}(i)=\frac{E\_{UCI-part1}}{E\_{tot}}N\_{RE}(i), $ **where** $ E\_{UCI-part1}$ **is the number of coded bits for UCI part 1**
* **If** $\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}$ **is smaller or equal to 11,**
	+ $Δ\_{TF,b,f,c,part1}\left(i\right)=10⋅log\_{10}(K\_{1}⋅\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}\right)/N\_{RE-part1}\left(i\right))$
	+ **If a HARQ-ACK codebook with** $O\_{UCI-part1,n^{'} }$ **bits is included in UCI part 1,  is used instead of** $O\_{UCI-part1,n^{'} }$ **for the HARQ-ACK codebook:**
		- $Δ\_{TF,b,f,c,part1}\left(i\right)=10⋅log\_{10}(K\_{1}⋅\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}-O\_{UCI-part1,n^{'} }+n\_{HARQ-ACK}(i)\right)/N\_{RE-part1}\left(i\right))$
	+ **If more than one HARQ-ACK codebooks are included in UCI part 1 (e.g. one due to SPS HARQ deferral, another for HARQ feedback for dynamic grant PDSCH(s)), then replacement of the number of HARQ-ACK codebook size by the associated** $n\_{HARQ-ACK}$ **can be applied to each HARQ-ACK codebook.**
* **otherwise**
	+ $Δ\_{TF,b,f,c,part1}\left(i\right)=10log\_{10}(2^{K\_{2}⋅BPRE\left(i\right)}-1) $**where**
		- **and**
		- $\begin{matrix}BPRE\left(i\right)=&&\left(\sum\_{n=1}^{N\_{UCI-part1}^{total}}‍O\_{UCI-part1,n}+O\_{CRC,UCI-part1}\right)&/N\_{RE-part1\left(i\right)}&\end{matrix}$
* **And** $Δ\_{TF,b,f,c}\left(i\right)$ **=** $Δ\_{TF,b,f,c,part1}\left(i\right)$ **is applied to both UCI parts.**
 |
| NEC | ***Proposal1:*** *When multiplexing both low-priority HARQ-ACK and high-priority HARQ-ACK on a high priority PUSCH scheduled by an UL non-fallback DCI,** *Support introducing an additional DAI field in UL DCI associated with high priority PUSCH for determining the total number of low priority HARQ-ACK.*

***Proposal2:*** *When multiplexing both low-priority HARQ-ACK and high-priority HARQ-ACK on a low priority PUSCH scheduled by an UL non-fallback DCI,** *The one DAI field in UL DCI associated with low priority PUSCH for determining the total number of low priority HARQ-ACK as Rel-16.*

***Proposal 3:***  *For multiplexing of a low priority Type-2 HARQ-ACK codebook and a high priority Type-1/Type-2 HARQ-ACK codebook on a PUCCH in Rel-17,** *Support introducing an additional DCI field in DCI associated with high priority HARQ-ACK for determining the total number of LP HARQ-ACK*
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| Samsung | **Proposal 2: When 1 bit LP HARQ-ACK is multiplexed with 1 bit HP HARQ-ACK, the HP HARQ-ACK bit is placed before the LP HARQ-ACK bit.****Proposal 4: RRC configures presence of a T-DAI field in a DL DCI format associated with HP HARQ-ACK to indicate the T-DAI of LP HARQ-ACK.** |
| QC | **Proposal 9: For HP UCI and LP HARQ-ACK (in type 2 codebook) multiplexing on a PUCCH, round up LP HARQ-ACK size to a nearest reference size, in the calculation of total number of RBs for HP and LP UCI and in the PUCCH resource set determination.**  |
| LG | **Proposal #6: Consider how to generate the HARQ-ACK payload per each of LP and HP for the multiplexing of LP/HP HARQ-ACK on PUCCH (or PUSCH), according to HARQ-ACK codebook type (e.g. Type-1/2/3 codebook).****Proposal #7: Introduce an additional field in the DL/UL HP DCIs for determining the number of LP HARQ-ACK bits multiplexed on PUCCH/PUSCH for both Type-1 and Type-2 codebooks, in order to handle potential ambiguity on the presence of LP HARQ-ACK feedback or the size of LP HARQ-ACK codebook.*** **For Type-1 codebook based LP HARQ-ACK, one of {full codebook, no HARQ-ACK} is indicated by 1-bit field in HP DCI.**
* **For Type-2 codebook based LP HARQ-ACK, one of {X-bit, Y-bit, Z-bit, W-bit} (where X < Y < Z < W) is indicated by 2-bit field in HP DCI.**

**Proposal #9: Consider the following aspect by taking potential missing of the DCI corresponding to HP HARQ-ACK by the UE into account.*** **The reserved REs corresponding to 2-bit HARQ-ACK on PUSCH are to be generated based on the beta offset configured for HP HARQ-ACK and to be mapped on LP PUSCH as well as HP PUSCH, even in case when there is no HP HARQ-ACK from UE perspective.**
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## 1st round discussion

Proposal for 1st round discussion:

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, the order of the multiplexed two bits could be [high-priority HARQ-ACK bit, low-priority HARQ-ACK bit].

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Proposal for 1st round discussion:

For the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection, a new T-DAI field can be RRC configured:

* For multiplexing HP HARQ-ACK and Type-2/Type-1 LP HARQ-ACK codebook,
	+ A T-DAI field in a DL DCI format associated with HP HARQ-ACK to indicate the T-DAI of LP HARQ-ACK.
	+ At most 2 bits are added to the DL DCI format associated with HP HARQ-ACK for the T-DAI of LP HARQ-ACK, compared to Rel-16.
* For multiplexing a LP Type-2/Type-1 HARQ-ACK codebook in a HP PUSCH,
	+ A T-DAI field in a UL DCI format scheduling the HP PUSCH to indicate the T-DAI of LP HARQ-ACK.
	+ At most 2 bits are added to the UL DCI format scheduling the HP PUSCH for the T-DAI of LP HARQ-ACK, compared to Rel-16.
* Note: If the new T-DAI field is not RRC configured, the ambiguity on LP HARQ-ACK type-1 codebook existence or LP HARQ-ACK type-2 codebook size due to DCI mis-detection is handled by gNB implementation.
* FFS whether/how to multiplex LP HARQ-ACK sub-codebook for CBG-based PDSCH on HP PUCCH or HP PUSCH with single new T-DAI field.

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Proposal for 1st round discussion:

Whether/how to handle the LP HARQ-ACK ambiguity in case of overlapping with HP SPS HARQ-ACK is up to gNB implementation.

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Proposal for 1st round discussion:

A separate RRC parameter configures enabling/disabling multiplexing of LP HARQ-ACK and HP SPS HARQ-ACK.

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## Multiplexing HARQ-ACK and SR with different priorities

## Inputs from Tdocs

**Issue 2.3-1: HP SR multiplexed with LP HARQ-ACK**

**Proposals from last meeting:**

When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,

* For positive SR, transmit HARQ-ACK on the SR PUCCH resource.
* For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.
* If the HP SR is PF0 and the HP SR is positive,
	+ 1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;
	+ 2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.
	+ Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.
* If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.
* Support: Huawei/Hisi, vivo, ZTE, OPPO, CATT, Panasonic, Spreadtrum, Lenovo (HP UCI bits of $O\_{UCI}=O\_{ACK}+1$), Sharp, LG
* Not support: Samsung

**Nokia proposal:**

* When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK:
	+ If there is 1bit HP HARQ-ACK and 1 bit LP HARQ-ACK: LP HARQ-ACK bit can be simply treated as a second HP HARQ-ACK bit, and the two HP HARQ-ACK bits are multiplexed with the HP SR using Rel-16/Rel-15 rules.
	+ If at least one of the HP HARQ-ACK payload size or LP HARQ-ACK payload size is greater than or equal to 2:
		- the 1-bit SR is appended to the HP HARQ-ACK bits, and these bits are treated as HP UCI/HARQ-ACK bits;
		- the number of HP UCI bits is *O*uci = *O*ACK + 1, where *O*ACK is the (original) number of HP HARQ-ACK bits;
		- reuse the (agreed) procedures for multiplexing of LP HARQ-ACK and HP HARQ-ACK on PUCCH resource with PF 2/3/4, i.e., PUCCH resource selection, separate coding, PRB determination, rate matching, power control, etc.

**Issue 2.3-2: HP SR + HP HARQ-ACK with PF0/1 multiplexed with LP HARQ-ACK**

**Extending agreement in last meeting to PF0/1:**

* When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK, information bits for K HP SRs are appended to HP HARQ-ACK bits, and treat them as HP UCI, where K (K≥1) PUCCHs semi-statically configured for K HP SRs overlap with the original PUCCH carrying the HP HARQ-ACK.
	+ The number of HP UCI bits is
		- Option 1: $O\_{UCI}=O\_{ACK}+\left⌈log\_{2}\left(K+1\right)\right⌉$, same as Rel-15;
			* OPPO, QC
		- Option 2: $O\_{UCI}=O\_{ACK}+1$
			* Ericsson, CATT, Spreadtrum, Sharp, Intel
	+ Reuse other procedures for multiplexing of LP HARQ-ACK and HP HARQ-ACK on PUCCH resource with PF 2/3/4, i.e. separate coding, PRB determination, rate matching and power control.
	+ If the HP HARQ-ACK is a dynamic HARQ-ACK, a PUCCH resource indicated by PRI is used for multiplexing.
	+ If the HP HARQ-ACK is a SPS HARQ-ACK, a PUCCH resource determined from the PUCCH resource(s) provided by sps-PUCCH-AN-List is used for multiplexing.

**Intel proposal:**

* Proposal 7: When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK, $O\_{UCI} $HP UCI bits can be multiplexed with LP HARQ-ACK in step 2, if the resultant HP PUCCH in step 1 uses HP HARQ-ACK PUCCH resource, otherwise, LP HARQ-ACK is dropped. $O\_{UCI}=O\_{ACK}+M$, where M is the number of HP SRs carried by resulant HP PUCCH in step 1.

**Lenovo proposal:**

* For overlapping PUCCH transmissions of a HP SR (i.e. positive SR), 1-bit HP HARQ-ACK, and 1-bit LP HARQ-ACK, UE multiplexes LP HARQ-ACK into a PUCCH resource for the HP SR and the HP HARQ-ACK by treating the LP HARQ-ACK as a HP HARQ-ACK bit.

**LG proposal:**

Consider following 6 cases when HP PUCCH format 0/1 carrying HP SR and HP HARQ-ACK overlaps with LP PUCCH carrying LP HARQ-ACK.

* Case 1: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK is based on PUCCH format 0
	+ The LP HARQ-ACK is to be dropped to avoid performance loss of HP UCI mapping on HP HARQ-ACK PF0 resource.
* Case 2: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK and HP SR are based on PF1 and PF1, respectively
	+ The LP HARQ-ACK can be multiplexed with the HP HARQ-ACK on HP SR PF1 resource.
* Case 3: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK and HP SR are based on PF1 and PF0, respectively
	+ After dropping the HP SR, the LP HARQ-ACK is multiplexed with HP HARQ-ACK on HP HARQ-ACK PF1 resource.
* Case 4: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK has dynamic HARQ-ACK
	+ The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in HP DCI.
* Case 5: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK is SPS HARQ-ACK with sps-PUCCH-AN-List
	+ The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in LP DCI (if exists).
	+ Alternatively (or if there is no LP DCI), the LP HARQ-ACK can be multiplexed with the HP UCI on HP SPS PF2/3/4 resource provided by sps-PUCCH-AN-List.
		- FFS on the case when total payload size of HP UCI + LP UCI exceeds the maximum payload size configured in sps-PUCCH-AN-List
* Case 6: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK is SPS HARQ-ACK with n1PUCCH-AN
	+ The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in LP DCI (if exists).
	+ Alternatively (or if there is no LP DCI), the LP HARQ-ACK can be dropped.

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| Company | Proposals/observations from Tdocs |
| HW | ***Proposal 14: When a PUCCH carrying HP SR with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PUCCH format 0/1,**** ***For positive SR, transmit HARQ-ACK on the SR PUCCH resource.***
* ***For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.***
* ***If the HP SR is PF0 and the HP SR is positive,***
	+ ***1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;***
	+ ***2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.***
	+ ***Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.***
* ***If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.***

***Proposal 16: For the collision between LP HARQ-ACK, LP SR and HP UCIs, LP SR can be jointly encoded with LP HARQ-ACK and follow the same handling rule as LP HARQ-ACK only and HP UCIs.***  |
| E/// | [Proposal 4 When a PUCCH carrying both HP HARQ ACK and SR (explicitly or implicitly) overlaps with a PUCCH carrying LP HARQ-ACK, treat the SR as a HP HARQ-ACK bit and reuse multiplexing solutions for PUCCH carrying HP HARQ-ACK overlapping with PUCCH carrying LP HARQ-ACK.](#_Toc95752008) |
| Nokia | * **Proposal 3.4: When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1:**
	+ **For positive SR, transmit LP HARQ-ACK on the SR PUCCH resource.**
	+ **For negative SR, transmit LP HARQ-ACK on the HARQ-ACK PUCCH resource.**
* **Proposal 3.5: When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK:**
	+ **If there is 1 bit HP HARQ-ACK and 1 bit LP HARQ-ACK: LP HARQ-ACK bit can be simply treated as a second HP HARQ-ACK bit, and the two HP HARQ-ACK bits are multiplexed with the HP SR using Rel-16/Rel-15 rules.**
	+ **If at least one of the HP HARQ-ACK payload size or LP HARQ-ACK payload size is greater than or equal to 2:**
		- **the 1-bit SR is appended to the HP HARQ-ACK bits, and these bits are treated as HP UCI/HARQ-ACK bits;**
		- **the number of HP UCI bits is *O*uci = *O*ACK + 1, where *O*ACK is the (original) number of HP HARQ-ACK bits;**
		- **reuse the (agreed) procedures for multiplexing of LP HARQ-ACK and HP HARQ-ACK on PUCCH resource with PF 2/3/4, i.e., PUCCH resource selection, separate coding, PRB determination, rate matching, power control, etc.**
 |
| vivo | ***Proposal 5: When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,**** ***For positive SR, transmit HARQ-ACK on the SR PUCCH resource.***
* ***For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.***
* ***If the HP SR is PF0 and the HP SR is positive,***
	+ ***1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;***
	+ ***2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.***
	+ ***Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.***
* ***If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.***
 |
| ZTE | ***Proposal 13:*** *When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,** *For positive SR, transmit HARQ-ACK on the SR PUCCH resource.*
* *For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.*
* *If the HP SR is PF0 and the HP SR is positive,*
	+ *1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;*
	+ *2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.*
	+ *Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.*
* *If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.*
 |
| OPPO | ***Proposal 5: When a PUCCH carrying HP SR only with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,**** ***For positive SR, transmit HARQ-ACK on the SR PUCCH resource.***
* ***For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.***

***Proposal 6: When a PUCCH with PF 0/1 carrying HP SR and HP HARQ-ACK overlaps with a PUCCH carrying LP HARQ-ACK, information bits for K (K≥1) HP SRs are appended to HP HARQ-ACK bits, and treat them as HP UCI, where K PUCCHs semi-statically configured for K HP SRs overlap with the original PUCCH with PF 0/1 carrying the HP HARQ-ACK.*** |
| CATT | ***Proposal 5: For multiplexing of HP SR with PF0/1 and LP HARQ-ACK with PF0/1,*** * ***For positive SR, transmit HARQ-ACK on the SR PUCCH resource.***
* ***For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.***
* ***If the HP SR is PF0 and the HP SR is positive,***
	+ ***1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;***
	+ ***2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.***
	+ ***Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.***
* ***If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.***

***Proposal 6: If a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK, 1 bit HP SR is appended to HP HARQ-ACK bits, and treated as HP UCI.*** |
| Pana | Proposal 4: When a PUCCH carrying HP SR with PUCCH format 0 overlaps with a PUCCH carrying LP HARQ-ACK with PUCCH format 0, the SR and HARQ-ACK are multiplexed and transmitted on the HARQ-ACK resource.Proposal 5: * **When a PUCCH carrying HP SR with PUCCH format 0 overlaps with a PUCCH carrying LP HARQ-ACK with PUCCH format 1, 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 6: When a PUCCH carrying HP SR with PUCCH format 1 overlaps with a PUCCH carrying LP HARQ-ACK with PUCCH format 0, no enhancement is necessary over Rel.16.Proposal 7:* **When a PUCCH carrying HP SR with PUCCH format 1 overlaps with a PUCCH carrying LP HARQ-ACK with PUCCH format 1, 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 bit is appended to SR information bit. For 2-bits HARQ-ACK information, bundling is used.**
 |
| DCM | **Proposal 4:*** *Agree the table for UE behavior on multiplexing eMBB HARQ-ACK and URLLC SR as a baseline. Further considerations are needed for down-selection.*

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|  | **URLLC SR PF0** | **URLLC SR PF1** |
| **eMBB HARQ-ACK PF0** | * Opt.1b: 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.1b/Opt.3: 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, i.e transmit eMBB HARQ-ACK on HARQ-ACK resource if SR negative, transmit eMBB HARQ-ACK on SR resource if SR positive.
 |
| **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.
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| Spreadtrum | 1. **Support the *Proposal for 3rd round discussion:***

***When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,**** ***For positive SR, transmit HARQ-ACK on the SR PUCCH resource.***
* ***For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.***
* ***If the HP SR is PF0 and the HP SR is positive,***
	+ ***1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;***
	+ ***2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.***
	+ ***Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.***
* ***If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.***
1. ***When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK, information 1 bit for the single HP SR is appended to HP HARQ-ACK bits, which is selected by UE.***
 |
| Samsung | **Proposal 1: Maintain Rel-16 operation and drop LP HARQ-ACK PUCCH when a LP HARQ-ACK PUCCH PF 0/1 overlaps with a HP SR PUCCH with positive SR.** |
| Intel | **Proposal 7: When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK,** $O\_{UCI} $**HP UCI bits can be multiplexed with LP HARQ-ACK in step 2, if the resultant HP PUCCH in step 1 uses HP HARQ-ACK PUCCH resource, otherwise, LP HARQ-ACK is dropped.** $O\_{UCI}=O\_{ACK}+M$**, where *M* is the number of HP SRs carried by resulant HP PUCCH in step 1.**  |
| Lenovo | **Proposal 2: For overlapping PUCCH transmissions of a HP SR (i.e. positive SR), 1-bit HP HARQ-ACK, and 1-bit LP HARQ-ACK, UE multiplexes LP HARQ-ACK into a PUCCH resource for the HP SR and the HP HARQ-ACK by treating the LP HARQ-ACK as a HP HARQ-ACK bit.****Proposal 3:** **When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1, similar to the case of LP HARQ-ACK with PF2/3/4, a UE can transmit SR on the SR PUCCH resource for positive SR and drop HARQ-ACK.****Proposal 4: When a PUCCH carrying HP SR and HP HARQ-ACK with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK and when the total number of HARQ-ACK bits including HP HARQ-ACK bits and LP HARQ-ACK bits is larger than 2, UE determines a PUCCH resource of priority index 1 based on HP UCI bits of** $O\_{UCI}=O\_{ACK}+1$ **(i.e. 1 bit for SR) and LP HARQ-ACK bits.** |
| Sharp | **Proposal 1: When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,*** **For positive SR, transmit HARQ-ACK on the SR PUCCH resource.**
* **For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.**
* **If the HP SR is PF0 and the HP SR is positive,**
	+ **1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;**
	+ **2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.**
	+ **Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.**

**If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.** |
| LG | **Proposal #5: Consider following 6 cases when HP PUCCH format 0/1 carrying HP SR and HP HARQ-ACK overlaps with LP PUCCH carrying LP HARQ-ACK.*** **Case 1: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK is based on PUCCH format 0**
	+ **The LP HARQ-ACK is to be dropped to avoid performance loss of HP UCI mapping on HP HARQ-ACK PF0 resource.**
* **Case 2: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK and HP SR are based on PF1 and PF1, respectively**
	+ **The LP HARQ-ACK can be multiplexed with the HP HARQ-ACK on HP SR PF1 resource.**
* **Case 3: HP HARQ-ACK + LP HARQ-ACK = 2 bits, and the HP HARQ-ACK and HP SR are based on PF1 and PF0, respectively**
	+ **After dropping the HP SR, the LP HARQ-ACK is multiplexed with HP HARQ-ACK on HP HARQ-ACK PF1 resource.**
* **Case 4: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK has dynamic HARQ-ACK**
	+ **The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in HP DCI.**
* **Case 5: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK is SPS HARQ-ACK with sps-PUCCH-AN-List**
	+ **The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in LP DCI (if exists).**
	+ **Alternatively (or if there is no LP DCI), the LP HARQ-ACK can be multiplexed with the HP UCI on HP SPS PF2/3/4 resource provided by sps-PUCCH-AN-List.**
		- **FFS on the case when total payload size of HP UCI + LP UCI exceeds the maximum payload size configured in sps-PUCCH-AN-List**
* **Case 6: HP HARQ-ACK + LP HARQ-ACK > 2 bits, and the HP HARQ-ACK is SPS HARQ-ACK with n1PUCCH-AN**
	+ **The LP HARQ-ACK is multiplexed with the HP UCI on HP HARQ-ACK PF2/3/4 resource determined by PRI indicated in LP DCI (if exists).**
	+ **Alternatively (or if there is no LP DCI), the LP HARQ-ACK can be dropped.**
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## 1st round discussion

Proposal for 1st round discussion:

When a PUCCH carrying HP SR with PF0/1 overlaps with a PUCCH carrying LP HARQ-ACK with PF0/1,

* For positive SR, transmit HARQ-ACK on the SR PUCCH resource.
* For negative SR, transmit HARQ-ACK on the HARQ-ACK PUCCH resource.
* If the HP SR is PF0 and the HP SR is positive,
	+ 1 bit LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=6} representing {NACK, ACK} respectively;
	+ 2 bits LP HARQ-ACK should be transmitted on the HP SR PUCCH resource by using m0 +{mCS=0, mCS=3, mCS=6, mCS=9} representing {NACK/NACK, NACK/ACK, ACK/ACK, ACK/NACK} respectively.
	+ Where m0 is configured by initialCyclicShift in the configuration of the HP SR PF0 resource in Rel-16.
* If the HP SR is PF1, and if the HP SR is positive, the 1 bit LP HARQ-ACK can be transmitted on the same SR resource with BPSK, while 2 bits LP HARQ-ACK can be transmitted on the same SR resource with QPSK.

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Proposal for 1st round discussion:

* When a PUCCH carrying HP SR and HP HARQ-ACK with PUCCH format 0/1 overlaps with a PUCCH carrying LP HARQ-ACK, information bits for K HP SRs are appended to HP HARQ-ACK bits, and treat them as HP UCI, where K (K≥1) PUCCHs semi-statically configured for K HP SRs overlap with the original PUCCH carrying the HP HARQ-ACK.
	+ The number of HP UCI bits is (to be down-selected from the two options):
		- Option 1: $O\_{UCI}=O\_{ACK}+\left⌈log\_{2}\left(K+1\right)\right⌉$, same as Rel-15;
		- Option 2: $O\_{UCI}=O\_{ACK}+1$
	+ Reuse other procedures for multiplexing of LP HARQ-ACK and HP HARQ-ACK on PUCCH resource with PF 2/3/4, i.e. separate coding, PRB determination, rate matching and power control.
	+ If the HP HARQ-ACK is a dynamic HARQ-ACK, a PUCCH resource indicated by PRI is used for multiplexing.
	+ If the HP HARQ-ACK is a SPS HARQ-ACK, a PUCCH resource determined from the PUCCH resource(s) provided by sps-PUCCH-AN-List is used for multiplexing.

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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)*

Agreement:

*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.*

* *It is understood that it is intended that the number of encoding chains for all UCI multiplexing combinations in Rel-17 should not exceed that in Rel-15/16.*

Agreement

*In NR Rel-17, [at least] 2 new set of beta offset values can be configured to the UE to indicate separate beta\_offset values for the following cases:*

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

Agreement

*For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK and LP HARQ-ACK would be transmitted on HP/LP PUSCH without CSI,*

* *HP HARQ-ACK and LP HARQ-ACK are separately encoded according to R15 TS 38.212 Clause 5.3.1 and Clause 5.3.3.*
* *Reuse R15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK in principle. FFS details.*
* *For LP HARQ-ACK, reuse R15 Part 1 CSI rate matching and RE mapping.*

Agreement

*For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and LP CSI consisting of two parts would be transmitted on LP PUSCH conveying UL-SCH,*

* *The CSI part 2 is dropped.*
* *Reuse R15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK in principle. FFS details.*
* *Reuse R15 CSI part 1 rate matching and RE mapping for LP HARQ-ACK.*
* *Reuse R15 CSI part 2 rate matching and RE mapping for LP CSI part 1.*
* *FFS for LP CSI consisting of single part.*

*Note: Apple raised concern on CSI being dropped unnecessarily which could cause performance and degrade usefulness of URLLC enhancement.*

**Agreement**

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a low-priority (LP) PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and ~~HP/~~LP CSI consisting of two parts would be transmitted on ~~HP/~~LP PUSCH not conveying UL-SCH, UE follows the same behaviour as that in case of PUSCH conveying UL-SCH.

For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a high-priority (HP) PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and HP~~/LP~~ CSI consisting of two parts would be transmitted on HP~~/LP~~ PUSCH not conveying UL-SCH, UE follows the same behaviour as that in case of PUSCH conveying UL-SCH.

**Agreement**

Define a new table for beta-offset values <1.

* + FFS for the values with the starting point as below.

|  |
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| $$β\_{offset}^{HARQ-ACK}$$ |
| [0.8] |
| [0.64] |
| [0.5] |
| [0.4] |
| [0.32] |
| [0.25] |
| [0.2] |
| [0.1] |

**Agreement**

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

* If HP HARQ-ACK, LP HARQ-ACK, and LP CSI including a single part would be transmitted on LP PUSCH,
	+ Reuse Rel-15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK.
	+ Reuse Rel-15 CSI part 1 rate matching and RE mapping for LP HARQ-ACK.
	+ Reuse Rel-15 CSI part 2 rate matching and RE mapping for the single part of LP CSI.

**Agreement**

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

* If HP HARQ-ACK, LP HARQ-ACK, and HP CSI including a single part would be transmitted on HP PUSCH,
	+ Reuse Rel-15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK.
	+ Reuse Rel-15 CSI part 1 rate matching and RE mapping for the single part of HP CSI.
	+ Reuse Rel-15 CSI part 2 rate matching and RE mapping for LP HARQ-ACK.

**Agreement**

In R17, if HP HARQ-ACK, LP HARQ-ACK and HP CSI consisting of two parts would be transmitted on HP PUSCH,

* LP HARQ-ACK is dropped.
* Reuse R15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK.

## Remaining issues on coding and resource determination

## Inputs from Tdocs

**Issue 3.2-1: Single-priority HARQ-ACK multiplexed with PUSCH**

* If HP HARQ-ACK without LP HARQ-ACK would be transmitted on LP PUSCH, the HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.
	+ Huawei/Hisi, ZTE, CATT, DOCOMO, Spreadtrum,
* If LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH, down-select from the two options:
	+ Option 1: The LP HARQ-ACK should be multiplexed on the HP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.
		- Huawei/Hisi, ZTE, CATT, DOCOMO
	+ Option 2: UE follows the same behaviour as that in case of PUSCH with HP HARQ-ACK.
		- Spreadtrum
	+ Option 3: Reuse Rel-15 HARQ-ACK rate matching and RE mapping for LP HARQ-ACK if no HP CSI is present, otherwise, HARQ-ACK rate matching equation should be revised by taking HP CSI into account and Rel-15 CSI rate matching without consideration of LP HARQ-ACK is used for HP CSI.
		- Intel

**Issue 3.2-2: LP CSI only**

* For the scenarios where a high-priority PUSCH overlaps with a PUCCH carrying low-priority CSI, the low-priority CSI is always dropped. (Not supported according to previous agreement)
	+ - HW, Nokia

**Issue 3.2-3: The problem of ambiguous LP HARQ-ACK payload size**

* If HP HARQ-ACK and LP HARQ-ACK would be transmitted on HP/LP PUSCH, a new T-DAI field for LP HARQ-ACK is added in HP DCI.
	+ HW, ZTE, CATT, Samsung (also RE reservation)

**Issue 3.2-4: Power control:**

* For multiplexing high-priority HARQ-ACK bits on a low-priority PUSCH, UE can be configured with a dedicated set of power control parameters to be used only when multiplexing high-priority HARQ-ACK on low-priority PUSCH in order to guarantee the required reliability for high-priority HARQ-ACK.
	+ Nokia
* Update the transmission power allocation order for Rel-17 by considering inter-priority UCI-on-PUSCH cases:
	+ LP PUSCH with HP HARQ-ACK should be of the same priority as HP PUSCH with HP HARQ-ACK, i.e., higher than HP PUSCH with CSI, as well as HP PUSCH only.
	+ LP HARQ-ACK on HP PUSCH should of the same priority as HP PUSCH only, i.e., lower than HP PUSCH with HP HARQ-ACK, as well as HP PUSCH with CSI.
	+ HW
* For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, reuse the same power control formula as in Rel-15.
	+ QC
* Regarding prioritization for transmission power reduction, any PUSCH including HP HARQ-ACK has the same priority for power allocation as HP PUCCH including HARQ-ACK and/or SR, or HP PUSCH including HARQ-ACK.
	+ DCM

**Issue 3.2-5: CG-UCI multiplexing**

**Lenovo proposal:**

* If UE is provided cg-UCI-Multiplexing and multiplexes HARQ-ACK of different priorities in a CG PUSCH, CG-UCI is jointly encoded with HP HARQ-ACK for the CG PUSCH of priority index 1, and CG-UCI is jointly encoded with LP HARQ-ACK for the CG PUSCH of priority index 0.

**Intel proposal:**

* When cg-UCI-Multiplexing is enabled, CG-UCI is jointly encoded with HP HARQ-ACK with beta offset for the HP HARQ-ACK, if both HP and LP HARQ-ACK are to be multiplexed into CG-PUSCH that includes CG-UCI.

**LG proposal:**

**Proposal #12: Support following four cases for the multiplexing of CG-UCI and HARQ-ACK on CG PUSCH.**

* **Case 1: {HP CG-UCI, HP HARQ-ACK, LP HARQ-ACK} on HP CG PUSCH**
	+ **HP CG-UCI and HP HARQ-ACK are jointly encoded, and LP HARQ-ACK is separately encoded from the jointly-encoded HP UCIs.**
* **Case 2: {HP CG-UCI, LP HARQ-ACK} on HP CG PUSCH**
	+ **HP CG-UCI and LP HARQ-ACK are separately encoded.**
* **Case 3: {HP HARQ-ACK, LP CG-UCI, LP HARQ-ACK} on LP CG PUSCH**
	+ **LP CG-UCI and LP HARQ-ACK are jointly encoded, and HP HARQ-ACK is separately encoded from the jointly-encoded LP UCIs.**
* **Case 4: {HP HARQ-ACK, LP CG-UCI} on LP CG PUSCH**
	+ **HP HARQ-ACK and LP CG-UCI are separately encoded.**

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| Company | Proposals/observations from Tdocs |
| HW | ***Proposal 17: If HP HARQ-ACK without LP HARQ-ACK would be transmitted on LP PUSCH with/without UL-SCH, HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping rules for the legacy HARQ-ACK.******Proposal 18: If LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH with/without UL-SCH, LP HARQ-ACK should be multiplexed on the HP PUSCH by reusing the rate matching/puncturing and RE mapping rules for the legacy HARQ-ACK.******Proposal 19: LP CSI only should be dropped when colliding with HP PUSCH.******Proposal 20: Additional LP UL DAI indication can be introduced in HP UL DCI to resolve the issue of ambiguous LP HARQ-ACK payload size in case of collision with HP PUSCH.**** ***2 bits LP UL DAI for Type 2 HARQ-ACK codebook to indicate the LP HARQ-ACK payload size.***
* ***1 bit LP UL DAI for Type 1 HARQ-ACK codebook to indicate the presence of LP HARQ-ACK.***
	+ ***The UE should not transmit LP Type 1 HARQ-ACK on HP PUSCH in case of UL DAI = 0 regardless of the fallback cases of receiving only a SPS release or only a fallback DCI on PCell with C-DAI=1.***

***Proposal 21: UE does not expect the overlapping between HP PUSCH and LP HARQ-ACK subject to Type 3 codebook/enh. Type 3 codebook/one shot retransmission.******Proposal 22: Update the transmission power allocation order for Rel-17 by considering inter-priority UCI-on-PUSCH cases:**** ***LP PUSCH with HP HARQ-ACK should be of the same priority as HP PUSCH with HP HARQ-ACK, i.e., higher than HP PUSCH with CSI, as well as HP PUSCH only.***
* ***LP HARQ-ACK on HP PUSCH should of the same priority as HP PUSCH only, i.e., lower than HP PUSCH with HP HARQ-ACK, as well as HP PUSCH with CSI.***
 |
| Nokia | * **Proposal 3.8: For the scenarios where a high-priority PUSCH overlaps with a PUCCH carrying low-priority CSI, the low-priority CSI is always dropped.**
* **Proposal 3.9: For the scenario where multiplexing high-priority HARQ-ACK bits on a low-priority PUSCH, UE can be configured with a dedicated set of power control parameters to be used only when multiplexing high-priority HARQ-ACK on low-priority PUSCH in order to guarantee the required reliability for high-priority HARQ-ACK.**
 |
| ZTE | ***Proposal 14:*** *If HP HARQ-ACK without LP HARQ-ACK would be transmitted on LP PUSCH, the HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.* ***Proposal 15:*** *If LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH, the LP HARQ-ACK should be multiplexed on the HP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.****Proposal 16:*** *For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and LP CSI consisting of two parts would be transmitted on LP PUSCH conveying UL-SCH,* * *If the leftover resources for LP HARQ-ACK and LP CSI part 1 is not sufficient, LP HARQ-ACK has higher priority than LP CSI part 1, and LP CSI part 1 may be partially dropped or compressed.*

***Proposal 17:*** *For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and LP CSI consisting of two parts would be transmitted on HP PUSCH conveying UL-SCH, LP CSI is dropped and multiplexing with HP PUSCH is not allowed.****Proposal 18:*** *For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK, LP HARQ-ACK, and HP CSI consisting of two parts would be transmitted on LP PUSCH conveying UL-SCH,* *HP CSI is allowed to multiplex with LP PUSCH. The multiplexing principle follows the way which HP HARQ-ACK, LP HARQ-ACK, and HP CSI consisting of two parts are transmitted on HP PUSCH conveying UL-SCH.****Proposal 19:*** *For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, if HP HARQ-ACK and LP HARQ-ACK would be transmitted on HP/LP PUSCH, a new T-DAI field for LP HARQ-ACK is added in HP DCI for PUSCH grant.* |
| CATT | ***Proposal 7: To avoid the impact on HP PUCCH/PUSCH due to missing DCIs corresponding to LP HARQ-ACK codebook, it is proposed to indicate the number of LP HARQ-ACK bits by a new T-DAI field in DCI corresponding to HP PUCCH/PUSCH.******Proposal 9: For multiplexing HP HARQ-ACK and LP CSI (if any) on LP PUSCH, or for multiplexing LP HARQ-ACK and HP CSI (if any) on HP PUSCH,**** ***Reuse R15 HARQ-ACK rate matching/puncturing and RE mapping for HP HARQ-ACK or LP HARQ-ACK.***
* ***Reuse R15 CSI part 1 rate matching and RE mapping for HP/LP CSI part 1.***
* ***Reuse R15 CSI part 2 rate matching and RE mapping for HP/LP CSI part 2.***
 |
| DCM | **Proposal 6:*** *If HP HARQ-ACK without LP HARQ-ACK would be transmitted on LP PUSCH, the HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.*
* *If LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH, the LP HARQ-ACK should be multiplexed on the HP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.*

**Proposal 8:*** Regarding prioritization for transmission power reduction, any PUSCH including HP HARQ-ACK has the same priority for power allocation as HP PUCCH including HARQ-ACK and/or SR, or HP PUSCH including HARQ-ACK.
 |
| Spreadtrum | 1. ***If HP HARQ-ACK without LP HARQ-ACK and w/o CSI would be transmitted on LP PUSCH, the HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.***
2. ***If LP HARQ-ACK without HP HARQ-ACK and w/o CSI would be transmitted on HP PUSCH, UE follows the same behaviour as that in case of PUSCH with HP HARQ-ACK.***
	* ***When only LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH,***
		+ ***Reuse R15 CSI part 1 rate matching and RE mapping for LP HARQ-ACK.***
	* ***When LP HARQ-ACK without HP HARQ-ACK and a single HP CSI would be transmitted on HP PUSCH***
		+ ***Reuse R15 CSI part 1 rate matching and RE mapping for the single HP CSI.***
		+ ***Reuse R15 CSI part 2 rate matching and RE mapping for LP HARQ-ACK.***
	* ***When LP HARQ-ACK without HP HARQ-ACK and two HP CSI parts would be transmitted on HP PUSCH***
		+ ***LP HARQ-ACK is dropped.***
		+ ***Reuse R15 CSI part 1 rate matching and RE mapping for the HP CSI part 1.***
		+ ***Reuse R15 CSI part 2 rate matching and RE mapping for the HP CSI part 2.***
 |
| Intel | **Proposal 9: When cg-UCI-Multiplexing is enabled, CG-UCI is jointly encoded with HP HARQ-ACK with beta offset for the HP HARQ-ACK, if both HP and LP HARQ-ACK are to be multiplexed into CG-PUSCH that includes CG-UCI.****Proposal 10: For multiplexing HP HARQ-ACK alone into a LP PUSCH, reuse Rel-15 HARQ-ACK rate matching and RE mapping for HP HARQ-ACK, and Rel-15 CSI rate matching and RE mapping for LP CSI, if any.** **Proposal 11: For multiplexing LP HARQ-ACK alone into a HP PUSCH, reuse Rel-15 HARQ-ACK rate matching and RE mapping for LP HARQ-ACK if no HP CSI is present, otherwise, HARQ-ACK rate matching equation should be revised by taking HP CSI into account and Rel-15 CSI rate matching without consideration of LP HARQ-ACK is used for HP CSI.**  |
| Lenovo | **Proposal 5**: If UE is provided cg-UCI-Multiplexing and multiplexes HARQ-ACK of different priorities in a CG PUSCH, CG-UCI is jointly encoded with HP HARQ-ACK for the CG PUSCH of priority index 1, and CG-UCI is jointly encoded with LP HARQ-ACK for the CG PUSCH of priority index 0. |
| QC | **Proposal 14: For multiplexing a high-priority (HP) HARQ-ACK and a low-priority (LP) HARQ-ACK into a PUSCH in R17, reuse the same power control formula as in Rel-15.**  |
| LG | **Proposal #12: Support following four cases for the multiplexing of CG-UCI and HARQ-ACK on CG PUSCH.*** **Case 1: {HP CG-UCI, HP HARQ-ACK, LP HARQ-ACK} on HP CG PUSCH**
	+ **HP CG-UCI and HP HARQ-ACK are jointly encoded, and LP HARQ-ACK is separately encoded from the jointly-encoded HP UCIs.**
* **Case 2: {HP CG-UCI, LP HARQ-ACK} on HP CG PUSCH**
	+ **HP CG-UCI and LP HARQ-ACK are separately encoded.**
* **Case 3: {HP HARQ-ACK, LP CG-UCI, LP HARQ-ACK} on LP CG PUSCH**
	+ **LP CG-UCI and LP HARQ-ACK are jointly encoded, and HP HARQ-ACK is separately encoded from the jointly-encoded LP UCIs.**
* **Case 4: {HP HARQ-ACK, LP CG-UCI} on LP CG PUSCH**
	+ **HP HARQ-ACK and LP CG-UCI are separately encoded.**
 |
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## 1st round discussion

Proposal for 1st round discussion:

* If HP HARQ-ACK without LP HARQ-ACK would be transmitted on LP PUSCH, the HP HARQ-ACK should be multiplexed on the LP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.
* If LP HARQ-ACK without HP HARQ-ACK would be transmitted on HP PUSCH, down-select from the options:
	+ Option 1: The LP HARQ-ACK should be multiplexed on the HP PUSCH by reusing the rate matching/puncturing and RE mapping for the legacy HARQ-ACK.”
	+ Option 2: UE follows the same behaviour as that in case of PUSCH with HP HARQ-ACK.
	+ Option 3: Reuse Rel-15 HARQ-ACK rate matching and RE mapping for LP HARQ-ACK if no HP CSI is present, otherwise, HARQ-ACK rate matching equation should be revised by taking HP CSI into account and Rel-15 CSI rate matching without consideration of LP HARQ-ACK is used for HP CSI.

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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, reuse the same power control formula as in Rel-15.

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## Enhancements for multiplexing parameters

## Beta-offset value and configuration

#### Inputs from Tdocs

**Issue 3.3.1-1: Support Beta-offset =0?**

* Yes
	+ Nokia, H3C, CATT, DCM
* No
	+ ZTE, QC

**Issue 3.3.1-2: Details for Beta-offset values**

* Confirm the Beta-offset values in bracket in last meeting:
	+ ZTE, OPPO
* Nokia proposal:

|  |
| --- |
| $$β\_{offset}^{HARQ-ACK}$$ |
| 0.8 |
| 0.64 |
| 0.5 |
| 0.4 |
| 0.32 |
| 0.2 |
| 0.1 |
| 0 |

* H3C proposal:

|  |
| --- |
| $$β\_{offset}^{HARQ-ACK}$$ |
| 0.8 |
| 0.64 |
| 0.5 |
| 0.4 |
| 0.32 |
| 0.25 |
| 0.2 |
| 0.1 |
| 0 |

**Issue 3.3.1-3: UCI coding rate greater than 1**

**QC proposal:**

The UE is not expected to receive an uplink DCI which indicates a UCI multiplexing on the PUSCH that results in the UCI coding rate greater than 1.

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| Company | Proposals/observations from Tdocs |
| Nokia | * **Proposal 3.6: For the scenarios of multiplexing HARQ-ACK bits in PUSCH of different priorities, RAN1 shall support the new table for beta-offset value <1 as below:**

|  |
| --- |
| $$β\_{offset}^{HARQ-ACK}$$ |
| 0.8 |
| 0.64 |
| 0.5 |
| 0.4 |
| 0.32 |
| 0.2 |
| 0.1 |
| 0 |

 |
| H3C | **Proposal 1: Define a new table for beta-offset values <1 as below.**

|  |
| --- |
| $$β\_{offset}^{HARQ-ACK}$$ |
| 0.8 |
| 0.64 |
| 0.5 |
| 0.4 |
| 0.32 |
| 0.25 |
| 0.2 |
| 0.1 |
| 0 |

 |
| ZTE | ***Proposal 20****: The beta\_offset should not be used to disable the intra-UE multiplexing UCI with data*.***Proposal 21****: Confirm the beta\_offset value in the brackets in last meeting agreement*. |
| OPPO | ***Proposal 8:*** ***Introduce 8 new values for Table 9.3-1 in TS38.213, as shown in Table 1.***Table 1: Mapping of beta\_offset values for HARQ-ACK information and the index signalled by higher layers

|  |  |
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| $I\_{offset,0}^{HARQ-ACK}$ or $I\_{offset,1}^{HARQ-ACK}$ or $I\_{offset,2}^{HARQ-ACK}$ or $I\_{offset}^{CG-UCI}$  | $β\_{offset}^{HARQ-ACK}$ or $β\_{offset}^{CG-UCI}$ |
| 16 | 0.8 |
| 17 | 0.64 |
| 18 | 0.5 |
| 19 | 0.4 |
| 20 | 0.32 |
| 21 | 0.25 |
| 22 | 0.2 |
| 23 | 0.1 |

 |
| CATT | ***Proposal 8: A value of zero for beta-offset can be introduced to indicate that LP UCI is not multiplexed on the HP PUSCH scheduled by the DCI.*** |
| DCM | **Proposal 7:*** *Support beta-offset =0 or a value disabling the UCI multiplexing on PUSCH of different priorities*
 |
| QC | **Proposal 12: Do not support beta-offset =0 in the new table for beta-offset values <1.** **Proposal 13: The UE is not expected to receive an uplink DCI which indicates a UCI multiplexing on the PUSCH that results in the UCI coding rate greater than 1.**  |
| LG | **Proposal #10: Consider whether/how to handle the case where actual coding rate of LP HARQ-ACK or LP CSI (which applies Rel-15 CSI part 2 rate-matching/RE mapping) on HP/LP PUSCH exceeds the coding rate provided based on the corresponding beta offset.** |
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#### 1st round discussion

Proposal for 1st round discussion:

The values for beta-offset values <1 are:

|  |
| --- |
| $$β\_{offset}^{HARQ-ACK}$$ |
| 0.8 |
| 0.64 |
| 0.5 |
| 0.4 |
| 0.32 |
| 0.25 |
| 0.2 |
| 0.1 |

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Proposal for 1st round discussion:

The UE is not expected to receive an uplink DCI which indicates a UCI multiplexing on the PUSCH that results in the UCI coding rate greater than 1.

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## Separate configurations of alpha values?

#### Inputs from Tdocs

* Yes
	+ LG
	+ 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
	+ 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 3.7: For the scenarios of multiplexing HARQ-ACK bits in a PUSCH of different priorities, do not support separate configurations of the scaling factor “alpha”.**
 |
| LG | **Proposal #13: Support separate configuration of alpha factor as well as beta offset 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.** |
|  |  |

## If no enough resource

## Inputs from Tdocs

When sufficient resource is not available for accommodating LP HARQ-ACK on HP PUSCH,

* Option 1: The LP HARQ-ACK is dropped
	+ Intel, Apple
* Option 2: The LP UCI is compressed/bundled.
	+ ZTE
* Option 3: UE does not expect this case
	+ Nokia

For the scenarios where multiplexing high-priority HARQ-ACK, low-priority HARQ-ACK and low-priority CSI part 1 onto low-priority PUSCH, UE does not expect insufficient resource for multiplexing all three UCIs.

* + Nokia

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| Company | Proposals/observations from Tdocs |
| Nokia | * **Proposal 3.10: For the scenarios where multiplexing low-priority HARQ-ACK onto high-priority PUSCH, UE does not expect insufficient resource for multiplexing low-priority HARQ-ACK.**
* **Proposal 3.11: For the scenarios where multiplexing high-priority HARQ-ACK, low-priority HARQ-ACK and low-priority CSI part 1 onto low-priority PUSCH, UE does not expect insufficient resource for multiplexing all three UCIs.**
 |
| ZTE | ***Proposal 22:*** *LP UCI compression is slightly preferred in case there is no enough resource left for LP UCI.* |
| Intel | **Proposal 12: In case of insufficient number of REs for LP HARQ-ACK, LP HARQ-ACK is dropped as legacy CSI part 2.**  |
| Apple | **Proposal 5-1: When UCI part 1 or UCI part 2’s capacity is exceeded, part of the HARQ-ACK feedback (initial HARQ bits / Type 1 or Type 2 codebook/deferred SPS HARQ-ACK) can be dropped.****Proposal 5-2: When UCI part 1 or UCI part 2’s capacity is exceeded, part of the HARQ-ACK feedback (initial HARQ codebook/retransmitted HARQ codebook) can be dropped.** |
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## 1st round discussion

Proposal for 1st round discussion:

For the scenarios where multiplexing low-priority HARQ-ACK onto high-priority PUSCH, down-select from the options:

* + Option 1: In case of insufficient resource for LP HARQ-ACK, LP HARQ-ACK is dropped
	+ Option 3: UE does not expect insufficient resource for multiplexing low-priority HARQ-ACK.

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Proposal for 1st round discussion:

For the scenarios where multiplexing high-priority HARQ-ACK, low-priority HARQ-ACK and low-priority CSI part 1 onto low-priority PUSCH, UE does not expect insufficient resource for multiplexing all three UCIs.

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# PHY prioritization between DG and CG PUSCHs with different priorities

## Agreements in previous meetings

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.*

**Agreement**

*For collision between HP CG PUSCH and LP DG PUSCH, if MAC delivers two MAC PDUs to PHY, PHY layer can make the prioritization so that the UE is expected to transmit the CG PUSCH and cancel the DG PUSCH at latest from the first symbol that is overlapping with the CG PUSCH.*

* *Note: For the DG PUSCH, it is up to UE implementation to handle OFDM symbols of the DG PUSCH before the start of HP CG PUSCH which are nonoverlapping with the HP CG PUSCH.*
* *FFS: How to handle the collision when there is repetition for CG and/or DG PUSCH*

Agreement

*For collision of LP DG-PUSCH and HP CG-PUSCH ~~of different priorities~~, the cancellation is applied per actual repetition, if LP DG-PUSCH and/or HP CG-PUSCH is repeated.*

Agreement

*For the overlapping between LP CG and HP DG, if MAC delivers two MAC PDUs to PHY, 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.*

* *On top of Rel-16 cancellation time (N2+d1) for PUCCH/PUCCH or PUCCH/PUSCH collision, additional time d3 is needed (which results N2+d1+d3 in total cancellation time) for LP CG-PUSCH and HP DG-PUSCH collision resolution.*
	+ *(Working assumption) d3 = {0,* $1,…,2^{μ+1}$*}symbol(s) upon UE capability report, where* $μ=0,1,2,3$ *for SCS=15/30/60/120kHz, respectively.*

Agreement

*For collision of HP DG-PUSCH and LP CG-PUSCH, the cancellation is applied per actual repetition, if HP DG-PUSCH and/or LP CG-PUSCH is repeated.*

**Agreement**

The following working assumption is confirmed

For the overlapping between LP CG and HP DG, if MAC delivers two MAC PDUs to PHY, 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.

* On top of Rel-16 cancellation time (N2+d1) for PUCCH/PUCCH or PUCCH/PUSCH collision, additional time d3 is needed (which results N2+d1+d3 in total cancellation time) for LP CG-PUSCH and HP DG-PUSCH collision resolution.
	+ d3 = {0, $1,…,2^{μ+1}$}symbol(s) upon UE capability report, where $μ=0,1,2,3$ for SCS=15/30/60/120kHz, respectively.

## Remaining issues

## Inputs from Tdocs

|  |  |
| --- | --- |
| Company | Proposals/observations from Tdocs |
| E/// | [Proposal 6 Similar to Rel-16, MAC is allowed to deliver two MAC PDUs to CG-vs-CG with different priorities in Rel-17.](#_Toc95752010)[Proposal 7 UE implementation makes sure that the low priority CG-PUSCH is cancelled and does not participate in intra-UE multiplexing/prioritization procedure, including UCI-PUSCH multiplexing.](#_Toc95752011)[Proposal 8 MAC may send two PDUs to two overlapping grants only if the later grant has higher PHY priority than the earlier grant.](#_Toc95752012)[Proposal 9 Adopt the same understanding as in Rel-16, i.e., when *lch-basedPrioritization* is configured, Rel-16 UL skipping cannot be enabled in Rel-17.](#_Toc95752013)[Proposal 10 For the scenario of HP DG vs LP CG, reuse Rel-15 timeline for the scheduling PDCCH.](#_Toc95752014)[Proposal 11 For the scenario of LP DG vs HP CG, no new timeline requirement is introduced for the scheduling PDCCH.](#_Toc95752015) |
| DCM | **Proposal 13:** * *Agree the proposed conclusion for overlapping of CG PUSCHs of different priorities. Two MAC PDUs are not expected to be delivered to PHY when different priorities CG PUSCHs are overlapping if Rel-17 intra-UE multiplexing is enabled.*
 |
| Intel | **Proposal 5: If UCI-MuxWithDifferentPriority or UCI-MuxWithDifferentPriority-secondaryPUCCH group is enabled for a cell group, it is not expected that MAC PDUs are delivered for two overlapping CG PUSCHs of different PHY priorities on a serving cell within the same cell group.**  |
|  |  |

# Spec clarification

## Inputs from Tdocs

**HW proposals:**

***Proposal 32: RAN1 should adopt the following TP to explicitly address the UE behavior of dropping LP HARQ-ACK in case the rest RE on the resultant PUCCH for LP HARQ-ACK is 0.***

|  |
| --- |
| **------------------ Text Proposal for 38.213 Clause 9.2.5.3 ------------------**If $\left(O\_{ACK,0}+O\_{CRC,0}\right)⋅r\_{1}+\left(O\_{ACK,1}+O\_{CRC,1}\right)⋅r\_{0}>M\_{RB}^{PUCCH}⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}⋅Q\_{m}⋅r\_{0}⋅r\_{1}$, the UE transmits the PUCCH over the $M\_{RB}^{PUCCH}$ PRBs. If $M\_{RB}^{PUCCH}⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}=\left⌈{\left(O\_{ACK,1}+O\_{CRC,1}\right)}/{\left(Q\_{m}⋅r\_{1}\right)}\right⌉$, the HARQ-ACK information bits of priority 0 are dropped. If a UE transmits a PUCCH that includes HARQ-ACK information bits of priority 0 and 1 using PUCCH format 1, the UE determines a power for the PUCCH transmission, as described in clause 7.2.1, assuming that all HARQ-ACK information bits have priority 1. |

## 1st round discussion

Proposal for 1st round discussion:

Adopt the following TP to explicitly address the UE behavior of dropping LP HARQ-ACK in case the rest RE on the resultant PUCCH for LP HARQ-ACK is 0.

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| **------------------ Text Proposal for 38.213 Clause 9.2.5.3 ------------------**If $\left(O\_{ACK,0}+O\_{CRC,0}\right)⋅r\_{1}+\left(O\_{ACK,1}+O\_{CRC,1}\right)⋅r\_{0}>M\_{RB}^{PUCCH}⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}⋅Q\_{m}⋅r\_{0}⋅r\_{1}$, the UE transmits the PUCCH over the $M\_{RB}^{PUCCH}$ PRBs. If $M\_{RB}^{PUCCH}⋅N\_{sc,ctrl}^{RB}⋅N\_{symb-UCI}^{PUCCH}=\left⌈{\left(O\_{ACK,1}+O\_{CRC,1}\right)}/{\left(Q\_{m}⋅r\_{1}\right)}\right⌉$, the HARQ-ACK information bits of priority 0 are dropped. If a UE transmits a PUCCH that includes HARQ-ACK information bits of priority 0 and 1 using PUCCH format 1, the UE determines a power for the PUCCH transmission, as described in clause 7.2.1, assuming that all HARQ-ACK information bits have priority 1. |

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| Company | Comments |
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