**3GPP TSG-RAN WG1 Meeting #106-eR1-2106639**

e-Meeting, Aug 16th – 27th, 2021

**Agenda item: 8.3.1.1**

**Source: Moderator (Nokia)**

**Title: Moderator summary #1 on HARQ-ACK feedback enhancements for NR Rel-17 URLLC/IIoT**

**Document for: Discussion and Decision**

# Introduction

As per chairman’s guidance, the email discussion is planned according to the following schedule:

[106-e-NR-R17-IIoT-URLLC-01] Email discussion on UE feedback enhancements for HARQ-ACK – Klaus (Nokia)

* 1st check point: August 19
* 2nd check point: August 25
* 3rd check point: August 27

**This document is structured as follows:**

* Sections 2 to 6 include the topics to be specified or at least further studied based on previous agreements, including sub-sections for the related email discussion rounds
	+ Please note, that HARQ-ACK payload size reduction is not in focus any longer based on the RAN#92 guidance (see section 3.2 of [RP-211569](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_92e/Docs/RP-211569.zip))
* There are two appendices, Appendix A containing the RAN1 agreements reached in AI 8.3.1.1 so far and Appendix B summarizing the companies’ proposals for easier referencing.

# SPS HARQ-ACK deferral for TDD

In this section, the proposed Rel-17 enhancements to prevent SPS HARQ-ACK deferral for TDD operation are summarized. The following related agreements from previous meetings are available on this topic:

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| Agreements: To address the issue of SPS HARQ-ACK dropping for TDD systems, focus on the following two options: * Option 1: Deferring HARQ-ACK until a next (e.g., first) available PUCCH
	+ FFS: Details including the definition of a next (e.g, first) available PUCCH, CB construction / multiplexing
* Option 2: Dynamic triggering of a one-shot / Type-3 CB type of re-transmission

FFS: Details on triggering and/or CB construction (incl. potential Type-3 CB optimizations) / multiplexingAgreements:* Support deferring SPS HARQ-ACK dropped due to TDD specific collisions until a next available PUCCH in Rel-17 based on semi-static configuration of slot format
	+ FFS: Details (including possible conditions for such a deferring, whether or not to consider semi-statically configured flexible symbols for PUCCH availability, etc.)
	+ Aim for minimal standardization efforts and UE complexity in implementation

Agreements:Further down-select between the following two options for SPS HARQ-ACK deferral: * Option 1: Joint RRC configuration of the SPS HARQ-ACK deferral per PUCCH cell group
	+ *Note: any SPS HARQ-ACK within a PUCCH cell group in principle is subject to deferral*
* Option 2: The SPS HARQ-ACK deferral is configured per SPS configuration
	+ *Note: part of sps-config, only HARQ-ACK of SPS PDSCH configurations configured for deferral is in principle subject to deferral*

Agreements: Rel-16 UCI multiplexing  / PUCCH overriding rules are reused for deferred SPS HARQ-ACK in the target slot, if applicable.Agreements: For SPS HARQ-ACK, the deferral from the initial slot/sub-slot determined by *k1* in the activation DCI to the target slot/sub-slot determined by *k1*+ *k1def*, the UE will check the validity of a target slot/sub-slot evaluating from one slot/sub-slot to the next sub/sub-slot (i.e. in principle *k1def* granularity is 1 slot/sub-slot)* FFS: if there is a limit on the minimum deferral considered the required UE processing (*k1def* ≥0)
* FFS: if there is a limit on the maximum deferral

Agreements: For SPS HARQ-ACK deferral, for the determination of valid symbols in the initial slot/sub-slot a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as ‘invalid’ or ‘no symbols for UL transmission’.Agreements: For SPS HARQ-ACK deferral, for the determination of valid symbols in the target slot/sub-slot a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as ‘invalid’ or ‘no symbols for UL transmission’.Agreements: For SPS HARQ-ACK deferral, support a limit on the maximum deferral of SPS HARQ in terms of *k1def* or *k1*+ *k1def** + FFS: limitation given by a maximum value of *k1def* or a maximum of *k1eff* =*k1*+ *k1def*
	+ FFS how the limitation is determined (e.g. by K1 set(s) or RRC configured limit)

Agreements: For SPS HARQ-ACK deferral, there is no lower limit defined for *k1def*Agreement: Restrict the further discussions on the initial slot handling for SPS HARQ-ACK deferral to the identified alternatives Alt. 1, Alt. 1A and 2. Agreement: For SPS HARQ-ACK deferral, the limit on the maximum deferral of SPS HARQ is defined in terms of *k1eff =k1*+ *k1def.*Working assumption: To handle the collision for the same HARQ process due to deferred SPS HARQ-ACK the following behaviour is to be specified: * In case the UE receives PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.

Agreement: For SPS HARQ-ACK deferral, the initial HARQ-ACK transmission occasion is considered to determine the out-of-order HARQ condition  |

* 1. Summary of companies input in their contributions

**RRC configuration of SPS HARQ-ACK deferral:**

* **Alt. 1 – per PUCCH group (3):** China Telecom [11], Mediatek [20], DoCoMo [26]
* **Alt. 2 – per SPS configuration (14):** vivo [2],Nokia/NSB [3], Ericsson [4], Spreadtrum [5], ZTE [6], Panasonic [10], OPPO [14], Qualcomm [16], LGE [18], ETRI [19], Intel [21], Sharp [24], TCL [25], CAICT [29]

**Maximum deferral value of k1+k1def =k1eff,max is determined as:**

* **Alt. 1 (5): Maximum k1 value in dl-DataToUL-ACK (5):** Huawei/HiSi [1], vivo [2], OPPO [14] (of the DCI format activating the SPS configuration), Mediatek [20], TCL [25]
	+ **k1+k1def corresponds to a valid k1 in dl-DataToUL-ACK (3):** vivo [2], LGE [18], TCL [25]
* **Alt. 2 (6): RRC configured:** Nokia/NSB [3] (per SPS configuration, value range up to 15), Spreadtrum [5], FGI/APT [15], Qualcomm [16], Intel [21], DoCoMo [26] (per SPS configuration)
	+ In case of a PUCCH transmission containing HARQ-ACK bits from different SPS configurations with different maximum deferral values, the maximum of those maximum deferral values is applied: Qualcomm [16]
* **Alt. 3 (1): Maximum value not defined but just given by the first available UL slot/sub-slot:** ZTE [6]
* **Additional input:**
	+ For PUCCH repetition, the maximum deferral value is applied per PUCCH repetition occasion: OPPO [14], ETRI [19] (?)
	+ If having SPS HARQ to be deferred with different k1eff, instead of dropping a subset of SPS HARQ, follow the last valid window of the SPS HARQ-ACK: ETRI [19]

**Definition of when to defer from the initial slot:**

* **Alt. 1 (11 Yes – 1 No)- Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid:** Huawei /HiSi[1], vivo [2], Nokia/NSB [3], Sony [7], Panasonic [10] (1st preference), NEC [12], Lenovo/Motorola [13], OPPO [14], FGI/APT [15], DoCoMo [26], CAICT [29] – No: Intel [21]
	+ **Moderator understanding:** *If SPS HARQ-ACK is multiplexed with e.g. dynamic PUCCH resource then it cannot be deferred. Needed discussion on handling of other configured PUCCH (such as CSI resources, see below)*
	+ Additional info:
		- multi-CSI-PUCCH-ResourceList, as well as pucch-CSI-ResourceList, is supported as candidate PUCCH resource(s) when performing SPS HARQ-ACK multiplexing with CSI: vivo [2], Nokia/NSB [3] (at least consider), CAICT [29]
		- Deferal decision should be done before the multiplexing decision: OPPO [14]
		- SPS PUCCH resources carrying N bits can be used as the candidates to check the validity of a SPS PUCCH resource for M-bit SPS HARQ-ACK associated to a slot, where N≥M: OPPO [14]
			* *Moderator question*: As the UE would be allowed to use a different, larger SPS PUCCH resource, would this then actually not be more Alt. 2 operation?
* **Alt. 1A (6x Yes): Deferral only, if the PUCCH resource configured by *SPS-PUCCH-AN-List-r16* or *n1PUCCH-AN* for the HARQ-ACK transmission assuming SPS HARQ-ACK only is not valid in the initial slot/sub-slot:** Huawei /HiSi[1], Ericsson [4], ZTE [6], CATT [9], Panasonic [10] (2nd preference), LGE [18] – **No**:
	+ **Moderator understanding:** *Defer SPS HARQ even if multiplexing & transmission based e.g on PRI in initial slot would be possible – i.e. deferral decision is done before the multiplexing decision*
	+ Additional info:
		- Deferral decision should be done before the multiplexing decision**:** ZTE [6]
		- Modification to Alt. 1A: UE could still defer to dynamically scheduled PUCCH within the initial slot: ZTE [6]
		- Modification to Alt. 1A: SPS HARQ-ACK can be still be multiplexed and transmitted in the initial slot (no changes to UCI multiplexing in the initial slot) in addition to the deferral: LGE [18]
		- Consider in addition semi-statically scheduled PUCCH transmission (CSI & SR) in the deferral condition: LGE [18]
* **Alt. 2 (8x Yes – 1x No): Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using SPS-PUCCH-AN-List-r16, n1PUCCH-AN or other configured PUCCH resource(s) is not valid:** Spreadtrum [5],Samsung [8], China Telecom [11], Qualcomm [16], Intel [21], TCL [25], Xiaomi [27], CAICT [29] – **No:** LGE [18]
	+ **Moderator understanding:** *Consider intra-slot deferral before inter-slot deferral*

Additional info:

* + Other configured PUCCH resources:
		- *PUCCH-ResourceSet:* Spreadtrum [5]
		- *multi-CSI-PUCCH-ResourceList:*Spreadtrum [5], CAICT [29]
	+ Apply some default rules to choose one resource: Spreadtrum [5] (smallest resource index or earliest starting symbols)
* **Other:**
	+ If an SPS HARQ-ACK PUCCH is determined to collide with the semi-statically configured flexible symbol in the slot, the SPS HARQ-ACK PUCCH should be transmitted: ZTE [6]
	+ If a PUCCH for SPS HARQ ACK info is dropped due to overlapping with DL or flexible symbol indicated by dynamic SFI, the “SPS HARQ ACK deferral to 1st available PUCCH” will not be applied to this case, i.e. no further deferral for this dropped PUCCH: Qualcomm [16]
	+ If a PUCCH containing HARQ-ACK & CSI is dropped, only the HARQ-ACK is deferred (the CSI is dropped): Qualcomm [16]
	+ Some semi-static flexible symbols can be configured to be ‘invalid’: ETRI [19]
	+ The decision on the deferral scheme / condition may be dependent on the gNBs PUCCH blind detection capability: CAICT [29]
	+ gNB configures if UL symbols indicated by SFI are ‘valid’ or ‘invalid’: CAICT [29]
	+ Support partial deferral of bits (N-N1 bits transmitted in initial slot, N2 bits are deferred): CAICT [29]

**Definition of next available PUCCH for inter-slot/sub-slot deferral (i.e. target slot):**

* **The earlier of *sps-PUCCH-AN-List-r16* or  *n1PUCCH-AN,* or a dynamically indicated PUCCH resource *(from*** ***PUCCH-ResourceSet*) (6):** vivo [2],Nokia/NSB [3], ZTE [6], TCL [25], DoCoMo [26], CAICT [29] (?)

Additional details:

* + *multi-CSI-PUCCH-ResourceList*, as well as *pucch-CSI-ResourceList* considered as additional candidate resources: vivo [5] (for a slot containing CSI),
	+ Consider the intra-UE multiplexing when determining the target slot: DoCoMo [26]
	+ Based on RRC configuration, dynamically scheduled PUCCH (using *PUCCH-ResourceSet*) can be used: CAICT [29]
* **First available slot defined by PUCCH of *sps-PUCCH-AN-List-r16* or *n1PUCCH-AN* (1):** CATT [9]
	+ Details:
		- *Initial SPS PUCCH resource defines validity in the target slot - i.e. only deferred payload defining the target slot (i.e. before any multiplexing)*: CATT [7]
* **Reuse the same condition as for the initial slot (2):** Samsung [8] (i.e. Alt. 2), LGE [18] (i.e. Alt. 1A)
	+ Next SPS PUCCH occasion of the SPS configuration: LGE [18] (FFS if possible for a different SPS configuration)
* **New PUCCH resources defined for deferred HARQ-ACK (1):** CAICT [29] (consider)
* **Additional input on the PUCCH resource selection in the target slot & target slot determination:**
	+ If the total payload size of deferred SPS HARQ and ‘non-deferred’ SPS HARQ-ACK cannot be accommodated in the target slot, nothing is transmitted and a new target slot for all SPS HARQ is determined: Huawei/HiSi [1], Qualcomm [16]
	+ Flexible symbols valid for PUCCH of deferred HARQ-ACK transmission: ZTE [6], TCL [25] (semi-static FS)
	+ The size of the deferred HARQ-ACK codebook is within the UCI size range configured for the selected PUCCH: ZTE [6]
	+ The number of the selected PUCCH symbols is not less than the number of original PUCCH symbols to ensure coverage: ZTE [6]
	+ The selected PUCCH has the earliest end symbol: ZTE [6]
	+ Further deferral if certain conditions not satisfied: ZTE [6]
	+ Target slot for SPS HARQ-ACK deferral is not changed after determination: CATT [9]
	+ PUCCH resource in the target slot determined based on the total HARQ payload size (SPS defer, SPS new, DG HARQ): CATT [9]
	+ If total payload size cannot be accommodated, transmit as many SPS HARQ-ACK bits and drop the other HARQ-ACK bits: Panasonic [10] (for deferred HARQ-ACK bits), OPPO [14] (transmit ‘urgent’ bits e.g. SPS HARQ not configured for deferral, and deferred HARQ-ACK bits close to the end of maximum deferral window) – **No** – Do not support partial deferral: Look for another target slot which can accommodate all deferred A/N bits: Qualcomm [16]
	+ If the payload/ code rate on a PUCCH resource is larger than a payload/ code rate threshold, the PUCCH resource is not available: China Telecom [11]
	+ Payload size determined by deferred and non-deferred SPS HARQ-Ack bits in a slot: FGI/APT [15]
	+ If the selected PUCCH carrying deferred A/N bits overlaps with DL transmission-scheduled by DCI in the target slot or DL/flexible symbol indicated by DCI format 2\_0, UE drops the deferred A/N bits without their further deferral: Qualcomm [15]

**Codebook construction / multiplexing in the target slot of deferred and non-deferred HARQ-ACK:**

* **Option 1: Same handling for all HARQ-ACK conditions (SPS only, Type 1 CB, Type 2 CB) (5):**
	+ **Deferred SPS HARQ-ACK bits are appended to the initial HARQ-ACK bits / CB in the target slot:** Nokia/NSB [3] (for simplicity due to same handling for all cases), CATT [9] (FFS Type 1 CB optimizations), Lenovo/Motorola [13], DoCoMo [26]
	+ **Concatenation of individual deferred CB(s) in order of time to the initial HARQ-ACK bits / CB:** Qualcomm [16](more than one deferred HARQ-ACK codebook can be deferred to the same PUCCH)
* **Option 2: Specific handling for different HARQ-ACK cases (SPS only, Type 1 CB, Type 2 CB) (6-7?):**
	+ **SPS only CB (new & deferred)**:
		- Alt. 1: Rel-16 rules to be applied: Huawei/HiSi[1], vivo [2], Sony [7], Intel [21]
		- Alt. 2: Deferred SPS HARQ-ACK bits amended to new, initial HARQ-ACK bits: ZTE [6],
	+ **Type 1 CB**:
		- Alt. 1: Map deferred SPS HARQ-ACK bits with k1+ k1def included in the K1 setto the Type 1 HARQ-ACK codebook, other SPS HARQ-ACK bits are appended: Huawei/HiSi [1], vivo [2], Ericsson [4] (?), ZTE [6], NEC [12]
		- Alt. 2: K1 set is extended by k1+k1def for Type 1 CB construction: vivo [2], LGE [18] (?, union of k1 sets), Intel [21]
		- Alt. 3: Pre-pend the deferred SPS HARQ-ACK to the Type 1 CB: ETRI [19]
	+ **Type 2 CB**:
		- Alt. 1: Rel-16 rules to be applied: Huawei/HiSi [1], vivo [2], Sony [7], Intel [21]
		- Alt. 2: Deferred SPS HARQ-ACK bits amended to new, initial HARQ-ACK bits: ZTE [6]
		- FFS: ETRI [19]
* **In addition:**
	+ The entire HARQ-ACK codebook containing at least one SPS HARQ-ACK for deferral is deferred (and not just the SPS HARQ-ACK bits to be deferred, but other SPS HARQ or DG PDSCH HARQ): Qualcomm [16]

**HARQ process collision:**

* **Do NOT confirm the RAN1#105-e working assumption, the deferred SPS HARQ-ACK can still be transmitted:** Sony [7]
* **Confirm the WA with the following update:** Samsung [8] (…to only allow SPS HARQ collision, but prevent collisions for DG PDSCH HARQ)
	+ *In case the UE ~~receives~~ is configured to receive a PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.*
* **Confirm the working assumption with an update to clarify that ‘received PDSCH’ is skipped and non-skipped SPS PDSCH:** Intel [21]
* **Confirm the WA on HARQ process collision:** LGE [18],
* **Change to HARQ buffer operation for HARQ process collision - drop the successfully decoded PDSCH soft-bits:** Sony [7]

**Other / misc:**

* Qualcomm [16]: Upon joint configuration of any combination of “SPS PUCCH HARQ deferral to 1st available PUCCH resource”, “PUCCH carrier switching” and “1-shot Enhanced Type 3 CB HARQ”, execution of “SPS PUCCH HARQ deferral to 1st available PUCCH resource” starts immediately after the SPS PUCCH HARQ deferral triggering and it stops:
	+ When appropriate PUCCH resource for the transmission of deferred HARQ is found, or
	+ When a request for “1-shot Enhanced Type 3 CB” is received, or
	+ When a “PUCCH-carrier switch command” is received in DCI (in case of more than 1 PUCCH CCs)
	+ When the maximum value of “k1\_def” is reached
* Change the definition of k1def by only counting UL and special slots: Xiaomi [27]
	1. 1st Round of email discusssions

During the 1st GTW session, the following was agreed:

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| **Agreement**The SPS HARQ-ACK deferral is enabled per SPS configuration* Note: part of sps-config, only HARQ-ACK of SPS PDSCH configurations enabled for deferral is in principle subject to deferral

AgreementDefinition of when to defer from the initial slot: * Alt1: Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid
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**Maximum deferral value of k1+k1def**

On the maximum deferral, the opinions seem to be slightly split (5 vs 6) between the maximum k1 value and RRC configuration. Moreover, some further clarifications would still be needed for both methods:

* For the maximum k1 value, is the maximum k1value given by the maximum across all configured K1 sets (incl. DCI format 1\_2 specific, LP/HP K1 sets) or is the maximum k1 value determined based on the applicable K1 set of the activation DCI (i.e. DCI format specific, LP/HP K1 sets)
* For the RRC configuration, is there a single max. deferral value applicable for all SPS configurations applicable for deferral, or is the value configurable per SPS configuration.

One company suggesting that there is no need to define a maximum deferral in terms of k1+k1def,but this would be against the earlier RAN1 agreement. Moreover, 3 companies think the deferral should be limited to existing k1 values in the K1 set in addition, but also here, based on earlier agreement to only discuss a limit on the minimum and maximum deferral.

Therefore, the following question is brought forward. **Please add your companies name directly to the Alternatives in the question and provide your additional comments or alternatives in the table below.**

**Question 2.1: The maximum deferral value in terms of k1+k1def is determinedas:**

* **Alt. 1: Maximum k1 value across all configured K1 sets / dl-DataToUL-ACK sets**
	+ *Note: this includes different PUCCH configurations, and DCI format specific configurations*
	+ **Supporting companies:** …
* **Alt. 2: Maximum k1 value of the K1 / dl-DataToUL-ACK set applied for the SPS activation**
	+ *Note: set is chosen based on the PHY priority and activating DCI format*
	+ **Supporting companies:** …
* **Alt. 3: by RRC configuration of a single maximum value applicable to all SPS processes**
	+ *Note: SPS configuration specific max. deferral value not supported*
	+ **Supporting companies:** …
* **Alt. 4: by RRC configuration per SPS configuration**
	+ *Note: SPS configuration specific max. deferral value supported*
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 5 – other options* |
| Nokia/NSB | Alt. 4, as this allows to take into account different latency constraints for different SPS configurations.  |
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**HARQ process collision:**

There had been mixed input on the RAN1#104bis-e working assumption. One company suggests to confirm the working assumption as is, two companies suggest minor modifications to the working assumption and one company thinks the working assumptions should not be confirmed, as the UE could at least store the HARQ-ACK information even though there would be ‘new DL-SCH data’ being received for that HARQ process (see discussions by Sony in [7]).

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| Working assumption: To handle the collision for the same HARQ process due to deferred SPS HARQ-ACK the following behaviour is to be specified: * In case the UE receives PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.
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The motivation by the two companies for a small change to the working assumption coming from the following facts:

* Samsung [8] discusses, that the OoO rule /collision should be limited to SPS PDSCH only but not apply to HARQ of DG PDSCH which should be avoided by gNB implementation.
	+ *In case the UE ~~receives~~ is configured to receive a PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.*
* Intel [21] discusses, that the ‘received’ may include skipped and non-skipped SPS PDSCH. One option here could be go to with the formulation suggested by Samsung, or alternatively (to not limit this to SPS PDSCH only) something like this could be done:
	+ *In case the UE is expected to receive~~s~~ PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.*

Let’s gather company input here, based one the following alternatives. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 2.2: With respect to the RAN1#104bis-e WA on the HARQ process collision handling for SPS deferral:**

* **Alt. 1: Confirm the WA without changes**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: Confirm the WA with the following changes:**
	+ *In case the UE ~~receives~~ is configured to receive a PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.*
	+ **Supporting companies:** …
* **Alt. 3: Confirm the WA with the following changes:**
	+ *In case the UE is expected to receive~~s~~ PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.*
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 4: Do not confirm the WA. The UE is expected to store at least the HARQ-ACK information of deferred SPS HARQ processes for deferred HARQ transmission**
	+ **Supporting companies:** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 5 – other options* |
| Nokia/NSB | Alt. 1 or Alt. 3For Alt. 2: we think there could be also collision with dynamically scheduled PDSCHAlt. 4: we don’t think that such operation is feasible  |
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**Target slot definition:**

Now that we defined the handling in the initial slot, we can also focus more on the target slot determination. There are plenty of different proposals on restrictions / conditions by different companies – well, let’s first try with the following set of questions here:

**Question 2.3: Definition of next available PUCCH for inter-slot/sub-slot deferral (i.e. target slot),**

* **Alt. 1: The earlier of *sps-PUCCH-AN-List-r16* or  *n1PUCCH-AN,* or a dynamically indicated PUCCH resource *(from PUCCH-ResourceSet*)**
	+ *Moderator comment / understanding: This is somehow aligned with the handling in the initial slot*
	+ **Alt. 1A: the target cell definition takes the HARQ-ACK multiplexing in the target slot into account**
		- **Supporting companies: Nokia/NSB,** …
	+ **Alt. 1B: the target cell does not takes the HARQ-ACK multiplexing in the target slot into account (i.e. target slot determination based only on deferred SPS HARQ-ACK bits)**
		- **Supporting companies:** …
* **Alt. 2: the First available slot defined by PUCCH of *sps-PUCCH-AN-List-r16* or *n1PUCCH-AN***
	+ **Alt. 2A: the target cell definition takes the SPS HARQ-ACK multiplexing (deferred / non-deferred) in the target slot into account**
		- **Supporting companies:** …
	+ **Alt. 2B: the target cell does not takes the HARQ-ACK multiplexing in the target slot into account (i.e. target slot determination based only on deferred SPS HARQ-ACK bits)**
		- **Supporting companies:** …
* **Alt. 3: New PUCCH resources defined for deferred HARQ-ACK**
	+ **Alt. 3A: the target cell definition takes the SPS HARQ-ACK multiplexing (deferred / non-deferred) in the target slot into account**
		- **Supporting companies:** …
	+ **Alt. 3B: the target cell does not takes the HARQ-ACK multiplexing in the target slot into account (i.e. target slot determination based only on deferred SPS HARQ-ACK bits)**
		- **Supporting companies:** …
* **Alt. 4: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 4 – other options* |
| Nokia/NSB | Alt. 1A, as this is first of all aligned with the initial slot handling and should take the HARQ multiplexing into account (to prevent overall dropping of e.g. SPS HARQ-ACK) |
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**Question 2.4: If after determination of a target slot, the deferred SPS HARQ-ACK cannot be transmitted (e.g. due to SFI indication or similar),**

* **Alt. 1: the deferred SPS HARQ-ACK bits are not further deferred and are dropped**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: the deferred SPS HARQ-ACK bits are further deferred (i.e. new target slot is determined)**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 – other options* |
| Nokia/NSB | Alt. 1 for simplicity. We don’t think we should over-optimize the operation here, as in the worst case re-transmission of cancelled HARQ can be applied as well.  |
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**Question 2.5: In case the total payload size of deferred HARQ-ACK cannot be accommodated in the determined target slot, the following is applied:**

* **Alt. 1: No SPS HARQ-ACK is transmitted, deferred and non-deferred HARQ-ACK bits are not transmitted and a new target slot is determined**
	+ **Supporting companies:** …
* **Alt. 2: partial deferral, i.e. only part of the deferred HARQ-ACK bits (that can be mapped) is transmitted**
	+ **FFS: handling of other bits, drop other deferred HARQ bits or even drop non-deferred SPS HARQ-ACK bits (as not ‘urgent’)**
	+ **Supporting companies:** …
* **Alt. 3: SPS HARQ-ACK is dropped (and not further deferred)**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 4: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 4 – other options* |
| Nokia/NSB | Alt. 3 for simplicity. We don’t think we should over-optimize the operation here, as in the worst case re-transmission of cancelled HARQ can be applied as well.Alt. 1 leads to unnecessary SPS HARQ-ACK deferral of new/initial SPS HARQAlt. 2: complicated specification operation |
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**Codebook construction / multiplexing in the target slot of deferred and non-deferred HARQ-ACK:**

Qualcomm [16] discusses that not just the SPS HARQ-ACK applicable for deferral is deferred, but the overall HARQ-ACK codebook (incl. DG PDSCH HARQ, SPS HARQ not subject to deferral) is deferred. To clarify if only the SPS HARQ-ACK bits are subject to deferral or the overall HARQ codebook, the following question is brought forward. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 2.6: For SPS HARQ-ACK deferral,**

* **Alt. 1: only SPS HARQ bits subject to deferral from HARQ-ACK codebook are deferred to the target slot**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: the entire HARQ-ACK codebook including at least one SPS HARQ-ACK bit subject to deferral is deferred to the target slot.**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 – other options* |
| Nokia/NSB | Alt. 1, as Alt. 2 leads to unnecessarily large payload size of the deferred codebook (e.g. for Type 1 CB when multiplexed with DG PDSCH HARQ) |
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Qualcomm [16] moreover discusses that SPS HARQ-ACK of more than one PUCCH slot could be subject to deferral and are then together deferred to a target slot. Just to be sure companies are having the same understanding, the following question is brought forward. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 2.7: For SPS HARQ-ACK deferral,**

* **Alt. 1: only the SPS HARQ bits subject to deferral from the ‘last’ initial PUCCH slot are subject to deferral (SPS HARQ bits from ‘earlier’ initial PUCCH slots are dropped)**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: SPS HARQ bits from more than one ‘initial PUCCH slot’ can be jointly deferred**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 – other options* |
| Nokia/NSB | Alt. 1 for simplicity. As for earlier issues, we don’t see a need to over-optimize the operation.  |
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Also, on the HARQ-ACK codebook construction in the target slot, there had been rather divergent input as there are separate cases to be considered, namely SPS HARQ-only, Type 1 CB and Type 2 CB to be configured. **Some companies prefer common handling for all cases for simplicity, and some companies prefer some case specific optimizations (specifically for Type 1 CB, for all other cases the different options proposed result in the same HARQ-ACK codebook size but may just lead to different bit ordering).**

**Question 2.8: For SPS HARQ-ACK deferral, the multiplex of deferred HARQ-ACK and initial HARQ-ACK bits in the target sloe is**

* **Alt. 1: common for all cases / combinations of deferred SPS HARQ and initial HARQ-ACK bits by simply appending the deferred SPS HARQ-ACK bits to the initial HARQ bits / codebook**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: the multiplexing is case specific, i.e. different procedures are applied to SPS HARQ-only, Type 1 HARQ codebook and Type 2 HARQ codebook**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| --- | --- |
| *Company* | *Comments or Alt. 3 – other options* |
| Nokia/NSB | Alt. 1 for simplicity. The only difference is for Type 1 HARQ-ACK codebook size but as the number of deferred SPS HARQ-ACK bits should not be that many compared to the Type 1 CB size, we see this as an unnecessary optimization (and specification complication).  |
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# Retransmission of cancelled HARQ

In this section, the proposed Rel-17 enhancements on retransmission of cancelled HARQ are summarized. The following related agreements from previous meetings are available on this topic:

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| Working Assumption: For at least HARQ-ACK re-transmission:* Support at least one enhanced Type 3 HARQ-ACK CB with smaller size (compared to Rel-16) in Rel-17
	+ *Definition of enhanced Type 3 CB:*
		- *The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook at least determined by RRC configuration*
		- *The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)*
* Support one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB (i.e. Alt. 3) in Rel-17
	+ *Details are FFS*
* Enhanced Type 3 HARQ-ACK CB and/or one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB are subject to separate UE capabilities

  |

* 1. Summary of companies input in their contributions

**Confirm the RAN1#105-5 working assumption:** CATT [9], NEC[9], Mediatek [20] (the overall WA assumption including both schemes and separate UE capabilities), DoCoMo [26]

**Enhanced Type 3 CB:**

**Size determination of enhanced Type 3 HARQ-ACK CB of smaller size based on dynamic indication or RRC configuration /activation only:**

* **RRC configuration (or activation) only (3 companies)**: Huawei/HiSi [1], Panasonic [10], ETRI [19]
	+ At least based on activation/release DCI for SPS and MAC CE for activation / release of serving cells: ETRI [19]
		- Reference time for the DCI / MAC CE needed to prevent size ambiguity due to dynamic signaling: ETRI [19]
* **Dynamic selection based on indication in the triggering DCI of one of multiple (configured) Type 3 CB(s) / sizes (10 companies):** vivo [2], Nokia/NSB [3] (for triggering DCI not scheduling PDSCH, otherwise only one / first Type 3 CB triggered), Spreadtrum [5] (can schedule PDSCH at the same time), Samsung [8] (N report states, if triggered no PDSCH is scheduled and unused field indicates report state), NEC [12] (reusing HPN field to indicate set of DL HARQ processes of SPS configurations), OPPO [14], Qualcomm [16] (direct indication of requested HARQ-IDs or HARQ-IDs within an indicated time window starting t0 slots before the triggering DCI), LGE [18], Intel [21] (indicating index to a table of different attributes, for both DCI scheduling PDSCH and not scheduling PDSCH), DoCoMo [26] (apply unused fields for DCI not scheduling PDSCH)
	+ Self-carrier triggering - triggering DCI on cell X triggers HARQ-ACK retransmission of HARQ processes of cell X: OPPO [14]
	+ If receiving multiple triggers for the same PUCCH slot, the enh. Type 3 CB for transmission contains the union of the triggered subsets: OPPO [14]

**Differentiation between Rel-16 Type 3 HARQ-ACK CB and (at least one) Rel-17 enhanced Type 3 HARQ-ACK codebook of smaller size:**

* Based on RRC configuration: CATT [9]
* Using RNTI: ETRI [19] (if only one enhanced Type 3 CB of smaller size is supported, otherwise, can use the dynamic indication in the DCI)

**PHY priority indication in the triggering DCI of the PUCCH (and the PUCCH configuration) carrying the Type 3 CB:**

* **Yes (13):** vivo [2], Nokia/NSB [3], Ericsson [4], ZTE [6], CATT [9], Panasonic [10], FGI/APT [15], Intel [21], Interdigital [22], Apple [23], Sharp [24], DoCoMo [26], WILUS [28]
* **No: -**
* **Details:**
	+ HARQ-ACK process information is mapped irrespective of corresponding latest scheduled or configured priority for each HARQ process (**8 Yes – 1x No**): vivo [2], Nokia/NSB [3], Ericsson [4], Samsung [8], CATT [9], LGE [18] (except for SPS HARQ process only CB), Intel [21], DoCoMo [26] – No: Only transmit HARQ-ACK of the indicated priority: Interdigital [22]
	+ For SPS HARQ process only Type 3 CB, the codebook can be constructed based on the priority of the SPS HARQ processes: LGE [18]
	+ CB construction should be studied first: ZTE [6]
	+ Separate configuration on presence of CBG & NDI for LP & HP enh. Type 3 CB: FGI/APT [15], Apple [23]
	+ Separate configuration of applicable HARQ process (groups) for LP & HP enh. Type 3 CB: Apple [23]
	+ For a triggering DCI not scheduling PDSCH, some unused bit-field can be used to indicate the PHY priority: Interdigital [22]
		- *Moderator question/comment*: We have already the PHY priority indication field in DCI formats 1\_1 and 1\_2 (if configured), couldn’t this field be used directly for indicating the PHY priority?

**Different suggested codebooks of smaller size:**

* Subset of configured CCs (3): vivo [2], Nokia/NSB [3], OPPO [14]
* Subset of configured HARQ processes (specific to CCs) (6): vivo [2], Nokia/NSB [3], Ericsson [4]. LGE [18], Intel [21] (based on dynamic indication), DoCoMo [26]
* Only activated CCs (2): Ericsson [4], ETRI [25] (?)
* SPS HARQ processes only (4): CATT [9], NEC [12], LGE [18] (separation from DG PDSCH HARQ-ACK or Rel-16 Type 3 CB by using a different RNTI), TCL [25]
* HARQ of specific SPS configurations of configured CCs (1): NEC [12]
* HARQ-IDs within time window starting t0 prior to the triggering DCI (1): Qualcomm [16]
* Dropped HARQ-ACK processes only (1): TCL [25]

**Type 3 CB triggering using DCI format 1\_2:**

* Yes (8): Nokia/NSB [3], Ericsson [4], Samsung [8], CATT [9], Panasonic [10], FGI/APT [15], Intel [21], WILUS [28]

**Handling of HARQ-ACK information which is not mapped to the enhanced Type 3 HARQ-ACK codebook of smaller size:**

* Alt. 1: Any ‘new, initial’ HARQ-ACK information for transmission in the same PUCCH slot that cannot be mapped to the enhanced Type 3 CB of smaller size is not transmitted/ dropped: Nokia/NSB [3], Intel [21]
* Alt. 2: UE is not expecting that ‘new, initial’ HARQ-ACK information cannot be mapped to the triggered enhanced Type CB of smaller size: Intel [21]

**Inclusion of SPS release to (enh.) Type 3 CB of smaller size:** WILUS (28)

**One-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource**

**Definition of HARQ-ACK codebook to be re-transmitted:**

* **Dynamic indication in the triggering DCI of the codebook(s) to be re-transmitted** (**10**): Nokia/NSB [3] (DCI does not schedule PDSCH using relative slot offset between original HARQ slot and target slot for PUCCH retransmission using unused field), ZTE [6] (‘Solution 2’: multiple field sizes which canceled/dropped HARQ-ACK codebook(s) to be transmitted), Samsung [8] (N bit trigger field for DCI that can also scheduled PDSCH or alternatively, 1 bit trigger in DCI and no PDSCH scheduled some unused field indicates PUCCH / UL slot of CB to be re-tx), CATT [9] (slot offset between triggering DCI and dropped HARQ indicated), Panasonic [10], Lenovo/Motorola [13] (slot offset between triggering DCI and cancel HARQ codebook and number of cancelled HARQ-ACK codebooks for re-transmission), LGE [18] (… indicate an UL slot and priority index so that intended HARQ-ACK codebook is chosen). Mediatek [20] (…slot index(-ices) pointing back in time selecting the codebook(s) that are requested for resending), DoCoMo [26] (all HARQ-Ack within a time window, where the scheduling DCI indicates the time window (slot offset, number of slots)), WILUS [28]
* **Last dropped HARQ-ACK codebook** (**2**): Ericsson [4], ZTE [6] (i.e. Solution 1)
* **Concatenation of dropped HARQ-ACK codebooks in order** (2xYes – 1x No): ZTE [6], Mediatek [20] – No: Only a single cancelled HARQ-ACK CB is re-transmitted: Qualcomm [16]
* gNB to request “*UE Indication of Cancelled HARQ CB*” from UE and therefore, gNB will be made aware if and which CB has been canceled (**1**): Qualcomm [16]
* PHY priority indication in the triggering indicates the PHY priority of the HARQ-ACK codebook to be re-transmitted (3): Mediatek [20], Nokia/NSB [3], DoCoMo [26]

**Triggering indication in the DCI:**

* **Explicit triggering indication in the DCI (3):** ZTE [6], Sony [7] (for DCI format 1\_1 using *One-shot HARQ-ACK request*, FFS for 1\_2), Mediatek [20]
	+ Can be triggered as early as possible after the conflict is determined: ZTE [6]
* **Implicit triggering by multiplexing on the next scheduled PUCCH resource indicated by a DCI for HARQ-ACK transmission (2):** Ericsson [4], Mediatek [20]
* **Implicit triggering by a DCI scheduling a re-transmission (1):** OPPO [14]
	+ A LP PUCCH, including the HARQ-ACK for HARQ process X, is cancelled by a HP PUCCH. UE receives a DCI indicating HARQ process X without NDI toggle, then LP PUCCH should be retransmitted based on the PRI and k1 indicated by the DCI.
* **Implicit triggering using a different RNTI (1):** Mediatek [20]
* **Implicit triggering of HARQ-ACK re-transmission based on indication of two HARQ-ACK transmission occasions in DCI (1):** Lenovo/Motorola [13]
	+ The DCI scheduling the initial PUCCH transmission also provides information on the HARQ-ACK re-transmission and UE uses this information for re-transmission if the initial transmission is canceled.

**Multiplexing of re-tx HARQ-ACK and new HARQ-ACK:**

* For Type 1 CB:
	+ only the Type 1 CB to be retransmitted is mapped (UE does not expect any new / initial HARQ-ACK in the same slot): Nokia/NSB [3]
	+ retransmitted HARQ-ACK bits appended to the initial HARQ-ACK codebook: CATT [9]
* For Type 2 CB, the Type 2 CB to be retransmitted is appended to the ‘new, initial’ Type 2 CB: Nokia/NSB [3], CATT [9]

**Other:**

* Consider first LP HARQ: ZTE [6] – No: Focus on HP HARQ: Mediatek [20]
* Triggering DCI to indicate the DAI of the Type 2 CB to be re-transmitted: Sony [7]
* In addition to trigger the re-tx of a HARQ-ACK CB, also the triggering of re-transmission of a PUCCH (incl. other UCI) should be considered: LGE [18]
* Support at least non-scheduling DCI triggering one-shot HARQ-ACK transmission: Interdigital [22]

**Other than enh. Type 3 & One-shot Triggering:**

**Enhanced Type 2 CB:** Clarification that PDSCH grouping for Enh-Type2 CB is within each PHY priority:vivo [2] (then readily available)

**Joint operation of one-shot triggering and e-Type 3 CB - UE selects one of these CBs depending on the number of dropped HARQ-ACK:** Sony [7]

* **If the number of dropped HARQ-ACK ≤ *THARQ*, the UE selects Dyn-ReTx CB**
* **If the number of dropped HARQ-ACK > *THARQ*, the UE selects e-Type 3 CB**

**Autonomous one-shot HARQ-ACK re-transmission for all or a subset of HARQ processes in an earlier CG-PUSCH resource:** Lenovo/Motorola [13]

**Automatic re-tx of canceled HARQ-ACK (if multiplexed on PUSCH) on the PUSCH re-transmission with the same resource allocation:** Qualcomm [16]

* Limited to UL-CI operation (i.e. dropping due to DCI format 2\_4 reception)
* If a PUSCH incl. HARQ is canceled, the cancelled HARQ-ACK is multiplexed on the PUSCH re-transmission automatically with the same resource allocation including same NDI, TBS, MCS, HARQ Process ID
* Only HARQ-ACK is to be re-transmitted (drop CSI)
* No multiplexing of new UCI on the PUSCH re-tx
* No support for partial automatic (re)transmission of cancelled HARQ bits

**Automatic (re)transmission of a single dropped LP HARQ-ACK CB. Automatic (re)transmission at the same PRI as the one for the initial PUCCH allocation; PRI allocation valid for up to N slots**: Qualcomm [16]

* Study joint configuration of automatic re-transmission, ‘One-short triggering’ and PUCCH carrier switching
* Proposed related procedure:

*Execution of* *“automatic (re)transmission of dropped or cancelled HARQ-ACK” starts immediately after HARQ-ACK dropping or cancellation and it stops:*

1. *when appropriate PUCCH resource for the transmission of the single dropped LP HARQ-ACK is found, or*
2. *upon reception of PUSCH allocation (DCI 0\_x) with same NDI and HARQ ID(s) as the allocation of the initially cancelled PUSCH via DCI 2\_4 , or*
3. *when a request for “1-shot HARQ (re)transmisison” is received, or*
4. *when a “PUCCH-Carrier Switch Command” is received in DCI (in case of more than 1 PUCCH CCs)*
5. *when the validity of the PUCCH Resource for the single dropped LP HARQ CB expires.*
	1. 1st Round of email discussions

***Moderator comments:***

4 companies suggest confirming the RAN1#105-e working assumption and not a single company raised any reservations. Therefore, the following is proposed:

**Proposal 3.1: Confirm the following RAN1#105-e working assumption:**

Working Assumption: For at least HARQ-ACK re-transmission:

* Support at least one enhanced Type 3 HARQ-ACK CB with smaller size (compared to Rel-16) in Rel-17
	+ *Definition of enhanced Type 3 CB:*
		- *The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook at least determined by RRC configuration*
		- *The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)*
* Support one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB (i.e. Alt. 3) in Rel-17
	+ *Details are FFS*
* Enhanced Type 3 HARQ-ACK CB and/or one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB are subject to separate UE capabilities

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB, … |
| Objecting companies |  |

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| *Company* | *Comments*  |
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**Type 3 CB related:**

**10 companies** indicated to support dynamic indication in the triggering DCI of the enh. Type 3 CB of smaller size to be transmitted, **whereas 3 companies** indicate that the enh. Type 3 HARQ-ACK codebook of smaller size should only be defined by RRC configuration and/or activation. Therefore, the following is proposed:

**Proposal 3.2: Support dynamic selection based on indication in the triggering DCI of one of multiple (configured) enh. Type 3 HARQ-ACK CB(s) of smaller size.**

* **Details are FFS**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
| Nokia/NSB | As discussed in our contribution, we think such dynamic indication is preferred as based on the dropped HARQ or not correctly received HARQ information, the gNB has the choice from one of more CBs to trigger.  |
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Companies had been proposing different enh. Type 3 CBs. Clearly, more than one CB could be supported (even if only based on RRC configuration and/or activation is supported), as a different codebook could be configured at certain times for a UE. So let’s try to get some input where companies stand here. **Please add your companies name directly to the Alternatives in the question and provide your additional comments or alternatives in the table below.**

**Question 3.1: Which of the following enhanced Type 3 CBs of smaller size do you support:**

* **Alt. 1: HARQ processes of a subset of configured CCs**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 2: Subset of configured HARQ processes (specific to CCs)**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 3: HARQ processes of only activated CCs**
	+ **Supporting companies:** …
	+ **Companies not supporting:** …
* **Alt. 4: SPS HARQ processes only (based on configured SPS processes)**
	+ **Supporting companies:,** …
	+ **Companies not supporting:** …
* **Alt. 5: SPS HARQ processes only (based on activated SPS processes)**
	+ **Supporting companies:** …
	+ **Companies not supporting:** …
* **Alt. 6: HARQ processes of specific SPS configurations of configured CCs**
	+ **Supporting companies:** …
	+ **Companies not supporting:** …
* **Alt. 7: HARQ-IDs / processes within time window starting t0 prior to the triggering DCI** (for details, check 16])
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 8: Dropped HARQ-ACK processes only**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 9: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 9 – other options* |
| Nokia, NSB | We support Alt. 1, Alt. 2 as they all have the size only dependent on configuration (and not any activation etc., which could lead to CB size ambiguities). The biggest issues with CB size ambiguity we see with Alt. 7 and Alt. 8 (which we actively oppose) but similar issues are there for Alt. 3 and Alt. 5. Alt. 4 & Alt. 6 can be by gNB implementation also achieved with Alt. 2, by configuring the related HARQ processes there (so no need to define this specifically).  |
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**Looking at the PHY priority handling, the following can be noted:**

* **13 companies** indicated the need to **support PHY priority handling** for enh. Type 3 HARQ-ACK codebooks of smaller size
* **8 companies** indicated, that the **HARQ-ACK information** of HARQ processes **should be mapped** to the enh. Type 3 HARQ-ACK codebooks of smaller size **irrespective of the PHY priority of the ‘HARQ-ACK’**– **whereas 1 company** indicated that **only HARQ-ACK information** which was associated with the **indicated priority** should be mapped
* **~4 companies** propose, that the **enh. Type 3 HARQ-ACK CB of smaller size** could have a **different structure or size depending on the priority**

Based on this, the following is proposed for Rel-16 Type 3 HARQ-ACK codebook and the Rel-17 enh. Type 3 HARQ-ACK CB of smaller size:

**Proposal 3.3:** **Support PHY priority handling for a PUCCH carrying the Rel-17 enhanced Type 3 HARQ-ACK CB of smaller size.**

* **The indicated PHY priority in the triggering DCI defines the PHY priority of the PUCCH carrying the Rel-17 enhanced Type 3 HARQ-ACK CB of smaller size.**
* **The A/N of HARQ processes is mapped to the Rel-17 enhanced Type 3 HARQ-ACK CB of smaller size irrespective of the PHY priority of the ‘A/N’ of the HARQ processes.**
* ***FFS:* *If the HARQ-ACK codebook size or structure is dependent on the PHY priority (e.g. separate configuration of CBG/NDI usage, separate configuration of HARQ IDs / CCs per priority, SPS HARQ-ACK process IDs of specific priority only for a SPS HARQ-ACK only codebook, …).***

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
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**Proposal 3.4:** **Support PHY priority handling for a PUCCH carrying the Rel-16 Type 3 HARQ-ACK CB in Rel-17.**

* **The indicated PHY priority in the triggering DCI defines the PHY priority of the PUCCH carrying the Rel-16 Type 3 HARQ-ACK CB.**
* **The A/N of HARQ processes is mapped to the Rel-16 Type 3 HARQ-ACK CB irrespective of the PHY priority of the ‘A/N’ of the HARQ processes.**
* **The support is subject to a Rel-17 UE capability and a UE supporting this capability can be configured in Rel-17 with Rel-16 Type 3 HARQ-ACK CB and PHY prioritization.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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There had been proposals for the PHY priority handling for the enh. Type 3 CB to support different configurability for the enh. Type 3 CB structure / content. Let’s check companies views on this:

**Question 3.2: For the PHY priority handling of the enhanced Type 3 CB(s) of smaller size, which Alt. do you support:**

* **Alt. 1: the enhanced Type 3 HARQ-ACK has the same structure, size and content (in terms of HARQ-IDs, CCs) irrespective of the PHY priority**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: PHY priority specific configuration of CBG and NDI usage**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 3: PHY priority specific configuration of subset of configured HARQ processes (specific to CCs)**
	+ **Supporting companies:** …
* **Alt. 4: For SPS HARQ process only CB, only the SPS HARQ-ACK process IDs of a specific priority are included**
	+ **Supporting companies:** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 5 – other options* |
| Nokia/NSB | Alt. 1 or Alt. 2 (removal of e.g. CBG for HP HARQ could be useful). Alt. 3 and Alt. 4 may be considered as unnecessary optimizations.  |
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**DCI format 1\_2 utilization**

**8 companies propose the usage of DCI format 1\_2 for the triggering (with nobody actively opposing).** Therefore, the following is proposed for Rel-16 Type 3 HARQ-ACK codebook and the Rel-17 enh. Type 3 HARQ-ACK CB of smaller size:

**Proposal 3.5:** **Support Rel-17 enhanced Type 3 HARQ-ACK CB of smaller size triggering using DCI format 1\_2 for a UE supporting DCI format 1\_2.**

* **The triggering support for DCI format 1\_2 is independently (from triggering using DCI format 1\_1) RRC configured to the UE.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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**Proposal 3.6:** **Support Rel-16 Type 3 HARQ-ACK CB triggering using DCI format 1\_2 in Rel-17 for a UE supporting DCI format 1\_2.**

* **The support is subject to a Rel-17 UE capability and a UE supporting this capability can be configured with DCI format 1\_2 triggering of the Rel-16 Type 3 HARQ-ACK CB.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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**Handling of ‘new’ HARQ-ACK information which cannot be mapped to the enhanced Type 3 HARQ-ACK codebook of smaller size:**

With the smaller Type 3 codebook size not all HARQ processes of all CCs are present in the codebook, and the question arises, what to do if in the PUCCH slot where the enh. Type 3 CB of smaller size is to be transmitted there is also ‘new, initial’ HARQ-ACK information scheduled that cannot be mapped to the enh. Type 3 CB. The following two options were discussed in TDocs by different companies:

* Alt. 1: Any ‘new, initial’ HARQ-ACK information for transmission in the same PUCCH slot that cannot be mapped to the enhanced Type 3 CB of smaller size is not transmitted/ dropped: Nokia/NSB [3], Intel [21]
* Alt. 2: UE is not expecting ‘new, initial’ HARQ-ACK information for transmission in the same PUCCH slot that cannot be mapped to the triggered enhanced Type CB of smaller size: Intel [21]

**Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below:**

**Question 3.3: How to handle multiplexing of ‘new, initial’ HARQ-ACK information scheduled for transmission in the same PUCCH slot that cannot be mapped to the enhanced Type 3 HARQ-ACK codebook of smaller size as the HARQ process is not part of the codebook:**

* **Alt. 1: ‘New, initial’ HARQ-ACK information which cannot be mapped is dropped / not transmitted**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: UE is not expecting ‘new, initial HARQ-ACK information’ which cannot be mapped.**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| --- | --- |
| *Company* | *Comments or Alt. 3 – other handling* |
| Nokia/NSB | Alt. 1 for simplicity. Alt. 2 may create limitations for gNB in requesting the Type 3 CB with SPS HARQ-ACK operation 🡪 not preferred  |
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**One-shot triggering related proposals:**

**10 companies** propose a dynamic indication in the triggering DCI to define the HARQ-ACK codebook(s) to be re-transmitted **whereas 2 companies think such indication is not needed** (.. and just the last dropped HARQ-ACK codebooks is to be re-transmitted)**.**

Looking at this strong majority preferring some dynamic indication the following is proposed:

**Proposal 3.7:** **The DCI triggering (by a DL assignment) the one-shot HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB** **dynamically indicates the HARQ-ACK codebook(s) / PUCCH occasions to be re-transmitted.**

* ***FFS details***

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
| Nokia/NSB | As laid out it our contribution, e.g. the HARQ-ID field could be used to indicated the PUCCH slot offset between the initial PUCCH slot and the re-transmission PUCCH slot (limited to indicate a single slot) |
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Looking at the input give, some companies think a single triggering DCI should only trigger the re-transmission of a single PUCCH occasion / HARQ-ACK CB whereas some companies think, a single triggering DCI could trigger the re-transmission of HARQ-ACK information of more than one PUCCH occasion. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below:**

**Question 3.4: A single DCI triggering the Rel-17 one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB can trigger the re-transmission of HARQ-ACK information of:**

* **Alt. 1: only a single HARQ-ACK CB**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: one or more HARQ-ACK CBs. The multiple HARQ-ACK CBs to be re-transmitted are concatenated.**
	+ **Supporting companies:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| --- | --- |
| *Company* | *Comments or Alt. 3 – other handling* |
| Nokia/NSB | Alt. 1: A single HARQ-ACK CB for simplicity.  |
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There had been different proposals on how to trigger indication ‘by a DL assignment’ is done. To see where companies stand, **please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below**

**Question 3.5: The Rel-17 one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB is done through:**

* **Alt. 1: Explicit triggering indication in the DCI through a DCI field (as for enh. Type 2 and Type 3 CB)**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: Implicit triggering by multiplexing on the next scheduled PUCCH resource indicated by a DCI for HARQ-ACK transmission**
	+ **Supporting companies:** …
* **Alt. 3: Implicit triggering by a DCI scheduling a re-transmission** (for details see the summary above & OPPO contribution in [14])
	+ **Supporting companies:** …
* **Alt. 4: Implicit triggering using a different RNTI**
	+ **Supporting companies:** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

|  |  |
| --- | --- |
| *Company* | *Comments or Alt. 5 – other handling* |
| Nokia, NSB | Alt. 1, following the enh. Type 2 and Type 3 CB triggering (for simplicity) |
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**PHY priority handling**

Although only suggested by 3 companies (but nobody actively against based on the TDocs), there is also for this feature the need for PHY priority indication to (a) define the PHY priority carrying the re-transmitted HARQ-ACK information and (b) define which HARQ-ACK codebook (LP or HP) is to be re-transmitted. Therefore, the following is proposed to be agreed:

**Proposal 3.8:** **Support PHY priority handling for the Rel-17 one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB.**

* **The indicated PHY priority in the triggering DCI defines the PHY priority of the PUCCH carrying the re-transmitted HARQ-ACK information.**
* **The indicated PHY priority in the triggering DCI is used to determine the HARQ-ACK information to be re-transmitted corresponding to the indicated PHY priority.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB |
| Objecting companies |  |

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| *Company* | *Comments*  |
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# PUCCH repetition enhancements (at least for HARQ-ACK), e.g., sub-slot based, etc.

In this section, the company positions on the support of PUCCH repetition enhancements (incl. sub-slot type of PUCCH repetition) are summarized. At RAN#90, the following clarification on the focus was done:

***RAN conclusion on IIoT scope:***

* *For handling of the PUCCH repetitions it is proposed to proceed as follows:*
1. *RAN1 to continue discussion on PUCCH repetition, whether to specify or not, in the IIoT/URLLC WI for single TRP.*
	1. *The following items are not within scope of the continued discussions in the IIoT/URLLC WI:*
		1. *DMRS-less PUCCH with UCI payload up to 11 bits*
		2. *PUSCH-repetition-Type-B like PUCCH repetition*
		3. *DMRS bundling across PUCCH repetitions*
2. *PUCCH repetition issues with multi-TRP to be handled in Fe-MIMO WI.*
* *For the UE CSI/HARQ-ACK feedback enhancements in the IIoT/URLLC WI, RAN1 work to continue the discussions. Status to be checked in March if any RAN level guidance needed.*
	+ *RAN1 to continue discussion on A-CSI on PUCCH, whether to specify or not.*

The following related agreements were achieved:

|  |
| --- |
| Agreements: Support sub-slot based PUCCH repetition for HARQ-ACK based on the Rel-16 PUCCH procedure for slot-based PUCCH applied to sub-slot based PUCCH* Note: the intention is to take the Rel-16 slot-based PUCCH by replacing with “sub-slot” appropriately, without further optimization unless necessary
* FFS whether or not there is any restriction for the applicability of sub-slot based PUCCH repetition for HARQ-ACK
* Dynamic repetition indication is supported also for sub-slot based PUCCH in Rel-17
	+ FFS: if the method to be specified in Cov. Enh WI for slot-based PUCCH repetition can be directly applied to sub-slot PUCCH or if changes are needed

Agreements: Support PUCCH repetition for PUCCH formats 0 and 2 at least for sub-slot based PUCCH repetition. * FFS: Support for slot-based PUCCH repetition
 |

* 1. Summary of companies input in their contributions

**Confirm the Cov. Enh. WI on the repetition factor configuration per PUCCH resource and indication using PRI (2)**: Huawei/HiSi [1], Ericsson [4]

* Seems directly applicable also for URLLC and sub-slot repetition (**7**): Nokia/NSB [3], ZTE [6], CATT [9] (applicable for slot & sub-slot based), Panasonic [10], LGE [18], Intel [21], Xiaomi [27]

‘***nrofSlots*’ also applicable for sub-slot based PUCCH repetition (2):** ZTE [6], Panasonic [10] (if sub-slot PUCCH repetition and dynamic repetition indication are separate features).

**Support slot-based PUCCH repetition for PUCCH Format 0 and Format 2 also for single TRP (6xYes – 2x No):** Huawei/HiSi [1], Nokia/NSB [3], Ericsson [4], Spreadtrum [5], Sharp [24], DoCoMo [26] – **NO, not needed**: ZTE [6], Xiaomi [27]

**Support sub-slot based PUCCH repetition also for other UCI types, including SR and CSI (7 vs 1)**: vivo [2], Nokia/NSB [3] (for Rel-15 RRC configured repetition factor *nrofSlots*), Ericsson [4] (dynamic repetition indication), ZTE [6], Samsung [8], CATT [9] (for dynamic repetition indication), Sharp [24] – **No – only for HARQ:** DoCoMo [26]

**Interaction of RRC configured & dynamic repetition indication:**

* **If dynamic repetition indication is available, ignore *nrofSlots*:** Ericsson [4], ZTE [6]
* **Leave the discussion to the Cov. Enh. WI:** Nokia/NSB [3]
* **FFS if for a PUCCH resource the dynamic repetition factor is not configured (use K=1 or *nrofSlots*):** LGE [18]

**Transient gaps (see discussion by Intel in [21] & RAN4 reply LS [R1-2102297])**

* **Introduce a mechanism of skipping UL symbols during repetitions mapped based on X-symbol gap, Y-sub-slot gap or invalid symbol pattern:** Intel [21]
	+ *Moderator question*: This skipping would only be applied if the TX parameters from PUCCH repetition to PUCCH repetition change? Otherwise (i.e. no TPC change, no FH, ..), such skipping would not be applied?

**Other suggested enhancements:**

* Drop a PUCCH repetition overlapping with a high-priority DG PUSCH to prevent high-priority UL-SCH data dropping: Nokia/NSB [3]
* Enable multiplexing of HARQ-ACK & SR (at least for PUCCH of priority index 1) to reduce SR latency: Nokia/NSB [3]
* Reducing the priority of a repetition according to the number of repetitions that have already been transmitted: Sony [7]
* For UCI mapping on PUSCH, scale the number or REs for UCI with the repetition number: Intel [21]
	+ *Moderator comment*: Based on the running specs, PUSCH overlapping with a PUCCH repetition occasion is to be dropped (i.e. no UCI multiplexing of a PUCCH on PUSCH) – is the intention to change this behavior as well?
	1. 1st Round of email discussions

Looking at the dynamic repetition indication working assumption from Cov. Enh. WI and the related information provided by companies, it seems that there is consensus between companies that that the working assumption from Cov. Enh. can be directly applied to URLLC and sub-slot based dynamic repetition indication.

**Proposed RAN1 conclusion: The dynamic repetition indication solution for slot-based PUCCH repetition from the RAN1#105-e working assumption from Cov. Enh. WI can be directly applied for dynamic repetition indication for sub-slot based PUCCH repetition.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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Two companies raised, that not just dynamic repetition indication for sub-slot PUCCH is supported but also semi-static configuration of PUCCH repetition factor using *nrofSlots*. It is the moderator’s understanding that this was the intention in the overall decision when talking about using the slot-based PUCCH repetition framework.

|  |
| --- |
| Agreements: Support sub-slot based PUCCH repetition for HARQ-ACK based on the Rel-16 PUCCH procedure for slot-based PUCCH applied to sub-slot based PUCCH* Note: the intention is to take the Rel-16 slot-based PUCCH by replacing with “sub-slot” appropriately, without further optimization unless necessary
* FFS whether or not there is any restriction for the applicability of sub-slot based PUCCH repetition for HARQ-ACK
* Dynamic repetition indication is supported also for sub-slot based PUCCH in Rel-17
	+ FFS: if the method to be specified in Cov. Enh WI for slot-based PUCCH repetition can be directly applied to sub-slot PUCCH or if changes are needed
 |

But just to be sure the following is proposed to clarify this and including some decision on the related UE capabilities:

**Proposal 4.1: For sub-slot based PUCCH repetition for HARQ-ACK, semi-static configured PUCCH repetition (i.e. using *nrofSlots*) and dynamic repetition factor based operation is supported.**

* **Sub-slot based PUCCH repetition based on semi-static configuration (i.e. using *nrofSlots*) and based on dynamic indication is subject to separate UE capabilities**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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Moreover, RAN1 agreed to support of PUCCH repetition for PUCCH format 0 and 2 for sub-slot based PUCCH repetition in general as well as for slot-based PUCCH repetition so far specifically only for M-TRP operation. **6 companies suggest to also support slot-based PUCCH repetition of PUCCH formats 0 and 2 also for S-TRP operation whereas 2 companies see no specific need for it.**

**Proposal 4.2: Support slot-based PUCCH repetition for PUCCH Format 0 and Format 2 also for single TRP operation.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

|  |  |
| --- | --- |
| *Company* | *Comments*  |
| Nokia, NSB | We don’t see a reason why this would be supported only for sub-slot based PUCCH repetition in general as well as for M-TRP and slot-based – but not for S-TRP operation there.  |
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**Sub-slot based PUCCH repetition for other UCI types:**

We so far only decided to support sub-slot based PUCCH repetition for HARQ-ACK. Several companies discussed in their TDocs the support of sub-slot based PUCCH repetition also for other UCI types, where most companies think some additional UCI could be support also but also some companies also think this is not needed. Moreover, there may be a difference when looking at semi-statically configured PUCCH repetition (i.e. using *nrofSlots*) where the PUCCH repetition factor is actually defined per PUCCH format compared to the case of dynamic repetition indication. To see where the group overall stands on this issue, the following question is brought forward. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 4.1: For sub-slot based PUCCH repetition, in addition to HARQ-ACK (agreed so far) the following UCI types should be support for , adopt the following:**

* **Alt. 1: SR based on semi-statically configured PUCCH repetition (i.e. using *nrofSlots*)**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 2: SR based on dynamic PUCCH repetition indication**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 3: P-CSI based on semi-statically configured PUCCH repetition (i.e. using *nrofSlots*)**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 4: P-CSI based on dynamic PUCCH repetition indication**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 5: SP-CSI based on semi-statically configured PUCCH repetition (i.e. using *nrofSlots*)**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 6: SP-CSI based on dynamic PUCCH repetition indication**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 7: Other**
	+ **Supporting companies:** …

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| --- | --- |
| *Company* | *Comments or Alt. 7 – other handling* |
| Nokia, NSB | We support SR for both cases (semi-static & dynamic) but don’t see a need to support for sub-slot PUCCH CSI-repetition with dynamic indication (for semi-static this is applicable, as this is PUCCH format specific).  |
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**Interaction of RRC configured & dynamic repetition indication:**

The interaction of RRC configured and dynamic repetition indication is discussed. 4 companies provided their input. Let’s try to get some input from more companies on this issue. The moderator would still add here one additional option not discussed by companies, namely that if dynamic repetition factor is not configured at all (i.e. for no PUCCH resource) then the PUCCH configured is applied – otherwise, the dynamic repetition factor applies (also if K=1 is configured or no repetition factor for a resource is configured).  **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 4.2: For sub-slot based PUCCH repetition, the interaction of RRC configured PUCCH repetition (i.e. using *nrofSlots*) and dynamic repetition indication the following handling is preferred:**

* **Alt. 1: Leave the discussion to the Cov. Enh. WI and apply the same handling as for slot-based PUCCH repetition**
	+ **Supporting companies: Nokia/NSB (1st preference),** …
* **Alt. 2: If dynamic repetition indication is available, ignore *nrofSlots***
	+ **Supporting companies:** …
* **Alt. 3: If K=1 is indicated dynamically or no repetition factor is configured for a PUCCH resource, apply *nrofSlots***
	+ **Supporting companies:** …
* **Alt. 4: No interaction – apply either dynamic repetition indication or RRC configured**
	+ **If dynamic repetition indicator is configured for any PUCCH resource, apply the dynamic repetition indication (incl. K=1 for PUCCH resources not having a dynamic repetition factor configured). Only if dynamic repetition indication is not configured for any PUCCH resource, the *nrofSlots* is applied**
	+ **Supporting companies: Nokia/NSB (2nd preference),** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

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| --- | --- |
| *Company* | *Comments or Alt. 5 – other handling* |
| Nokia/NSB | We think we should leave this to the Cov. Enh. WI. If to be decided here for sub-slot based PUCCH, we think Alt. 4 is the cleanest solution (i.e. either semi-static configuration or dynamic indication based on the RRC configuration).  |
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**Transient gaps (see discussion by Intel in [21] & RAN4 reply LS in R1-2102297)**

Intel raised the issue of transient gaps needed in case there is back-to-back PUCCH repetition of PUCCH with different transmission parameters (such as FH due to different RB allocation and PUCCH TPC / power change) based on RAN4 LS in R1-2102297.

Intel suggesting 3 ways how to define this:

* based on X-symbol gap
* based on a Y-sub-slot gap
* based on an invalid symbol pattern

It is the moderator’s understanding, that a similar discussion on this restriction was carried out in RAN1 already in the context of M-TRP in NR-feMIMO with the following conclusion from RAN1#104bis:

|  |
| --- |
| **Conclusion**With reference to the normative work on NR-feMIMO:Related to the support of switching gap between UL transmissions towards two TRPs in RAN1 specifications, there is no consensus in RAN1 to specify symbol gap(s) for the following cases* PUSCH Type A
* PUCCH scheme 1
* PUSCH Type B
* PUCCH scheme 3

The above applies for the case included in the LS from RAN4 in R1-2102297. |

Intel raised the issue of transient gaps needed in case there is back-to-back PUCCH repetition of PUCCH with different transmission parameters (such as FH, TPC,..) based on RAN4 LS. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 4.3: For handling transient gaps for 2OS sub-slot PUCCH (see discussion by Intel in [21] & RAN4 reply LS in R1-2102297, adopt the following:**

* **Alt. 1: Handling based on an X-symbol gap**
	+ **Supporting companies:** …
* **Alt. 2: Handling based on a Y-sub-slot gap**
	+ **Supporting companies:** …
* **Alt. 3: Handling based on an invalid symbol pattern**
	+ **Supporting companies:** …
* **Alt. 4: Follow the (final) operation defined in NR-feMIMO**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 5: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 5 – other handling* |
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# Type 1 HARQ CB based on sub-slot PUCCH config

In this section, the Type 1 HARQ-ACK codebook support for sub-slot based PUCCH configuration is discussed. The following related agreements from previous meetings are available on this topic:

|  |
| --- |
| Agreement: Support Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration in Rel-17.* The properties of the Type-1 HARQ-ACK codebook for sub-slot PUCCH at least includes that a PDSCH TDRA is associated with a UL /PUCCH sub-slot if the end of the PDSCH overlaps with the associated sub-slot determined by a k1 in the set of sub-slot timing values K1.
* FFS: whether the PDSCH TDRA grouping is performed per DL slot or sub-slot
	+ Decide between PDSCH TDRA grouping per DL slot and sub-slot during RAN1#105-e
 |

* 1. Summary of companies input in their contributions

**TDRA grouping:**

* **Option 1 (7): TDRA pruning/grouping per DL slot after TDRA determination per UL sub-slot.**
	+ **Support:** Huawei/HiSi [1], Nokia/NSB [3], ZTE [6], Samsung [8], CATT [9], OPPO [14] (?), Qualcomm [16] (… TDRA pruning based on the Rel-15 approach)
	+ **Arguments**: reduce the CB size (Huawei/HiSi [1], Nokia/NSB [3])
* **Option 2 (4): TDRA pruning/grouping per ‘DL’ sub-slot after TDRA determination per UL sub-slot.**
	+ **Support:** Spreadtrum [5], NEC [12], TCL [25], DoCoMo [26]
	+ **Arguments**: Grouping per slot results in larger Type 3 CB: Spreadtrum [5], less specs changes: TCL [25], DoCoMo [26]

**Further provided details on the procedure:**

* Huawei/HiSi [1]
	+ *Step 1: Determine DL slots consisting of DL sub-slots associated to the determined UL sub-slot*
	+ *Step 2: In each determined DL slot, prune the PDSCH SLIVs whose ending symbols overlap with DL sub-slots that not associated to the determined UL sub-slot based on K1 set.*
	+ *Step 3: Perform per slot SLIV splitting among the remaining SLIVs for each slot to generate the TDRA groups, each group of which is associated with the HARQ-ACK bit field.*
* Ericsson [4]
	+ Support Type-1 HARQ codebook for sub-slot HARQ-ACK by updating the pseudo code for determining a set of occasions for candidate PDSCH reception where the ratio $2^{μ\_{DL}-μ\_{UL}}$ is changed to $\left⌊2^{μ\_{DL}-μ\_{UL}}/N\right⌋$, where N is the number of sub-slots in an UL slot.
	+ Example pseudo code for pruning/grouping per DL slot presented
* Spreadtrum [5]
1. For a UCI to be sent in sub-slot n, determine the union set of K1 values in unit of sub-slot according to the DCI formats the UE is configured to monitor PDCCH.
2. Determine the union set of row indexed of TDRAs for DCI formats the UE is configured to monitor PDCCH
	1. At sub-slot n-K1 with the given value K1, all the PDSCH occasions (end symbols are whining sub-slot n-K1) indicated in the TDRA tables configured by higher layers are considered to determine the codebook size.
	2. If PDCCH starting symbol as the reference of SLIV is supported, the corresponding SLIVs with starting symbol $S$ replaced by $S+S\_{0}$ should also be added into candidate PDSCH occasion sets.
3. The PDSCH occasions that conflict with TDD DL/UL configuration are removed first. The remaining PDSCH occasions selection for determining the codebook size is given as the procedure below:
4. Select T to be smallest end symbol index of all the available SLIVs in sub-slot n-K1.
5. Move the corresponding SLIV with ending symbol T into the chosen SLIV set $∅$.
6. Cancel the remaining SLIVs that starts no later than T.
7. Go back to step 1) until all the SLIVs ending in sub-slot n-K1 are looped and get the final SLIV set $∅$ to generate HARQ-ACK bits.
* ZTE [6]
	+ *Determine the DL slot corresponding to the type1 HARQ-ACK codebook;*
	+ *Within the determined DL slot, if the end symbol of a PDSCH TDRA does not overlap with the determined UL sub-slot (n-k1), then delete the PDSCH TDRA from the PDSCH TDRA of the determined DL slot;*
	+ *The remaining PDSCH TDRA in the determined DL slot is divided into SLIV groups per slot level;*
	+ *Generate HARQ-ACK information for each SLIV group.*
* OPPO [14]
	+ *Step 1: Determine candidate DL subslots corresponding to one UL subslot based on the K1 set.*
	+ *Step 2: If the last symbol of a PDSCH TDRA row r is not in the candidate DL subslots, row r is removed from the candidates of TDRA rows.*
	+ *Step 3: Determine occasions for candidate PDSCH receptions based on the remaining PDSCH TDRA rows.*

**Other:**

* Further study the HARQ-ACK location determination for SPS release in the Type-1 HARQ-ACK codebook based on sub-slot PUCCH configuration: NEC [12]
* HARQ-ACK bits will only be present in the semi-static type-1 codebook if the corresponding sub-slot has at least one PDCCH transmission or SPS PDSCH reception: NEC [12]
	1. 1st Round of email discussions

On the Type 1 HARQ-ACK codebook for sub-slot PUCCH, there is a single FFS pending namely if the TDRA grouping/pruning should be done per DL slot or per (UL) sub-slot.

* **7 companies** indicated their support **per DL slot**, as this may lead to a smaller Type 1 HARQ-ACK codebook size
* **4 companies** indicated their support **per (DL) sub-slot**
	+ 2 companies raise the point that this may be simpler, but acknowledge the issue of (slightly) larger Type 1 HARQ-ACK CB size.
	+ 1 company (Spreadtrum) argues that grouping per slot would lead to larger CB size, which seems to be a different understanding compared to the rest of the companies (and the discussions from RAN1#104bis-e)

As the majority of companies suggesting the grouping per DL slot and there seems to be also the technical merit of a smaller Type 1 CB size, the following is proposed:

**Proposal 5.1: For Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration in Rel-17, the TDRA pruning/grouping is performed per DL slot after TDRA determination per UL sub-slot.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
| --- | --- |
| Supporting companies | Nokia, NSB,  |
| Objecting companies |  |

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| --- | --- |
| *Company* | *Comments*  |
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In addition to the decision on if the TDRA grouping/pruning is done per DL slot or sub-slot, some companies already provided some details on the way this is then to be captured in 38.213 (either based on suggested steps or directly providing some related TPs).

It is the moderators understanding, that when taking the decision to support Type 1 HARQ-ACK codebook for sub-slot based PUCCH that the time spent on discussing related issues should be minimized. The moderator does not see it as essential to discuss the final structure in 38.213, as this can be left to the 38.213 editor to implement at the end of the release. Therefore, the following is proposed:

**Proposal 5.2: Do not discuss any pseudo-code / TPs on the Type 1 HARQ-ACK codebook construction for sub-slot based PUCCH during the Rel-17 WI phase.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

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| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
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Moreover, one companies proposes further enhancements to the Type 1 CB for sub-slot PUCCH (see ‘Other’ in the summary). Also, here it is the moderator’s understanding, when taking the decision on the support the FFS point on additional enhancements had been removed to limit the further work on this feature (and not take time from other HARQ-ACK enhancements of Sec. 2, 3, 4 & 6). Therefore, the following is proposed:

**Proposal 5.3: Do not discuss any further enhancements or optimizations for the Type 1 HARQ-ACK codebook for sub-slot based PUCCH during the Rel-17 WI phase.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

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| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
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# PUCCH carrier switching for HARQ feedback

In this section, PUCCH carrier switching (at least) for HARQ-ACK feedback is discussed. The following related agreements from previous meetings are available on this topic:

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| Agreements: In the studies on PUCCH carrier switching for HARQ-ACK, PUCCH carrier switching for different cells operated is considered only for cells that are part of the active UL CA configuration.Agreements: **For further study on** **whether and how to support** **PUCCH carrier switching** **in a PUCCH group, focus on the following three alternatives:*** **Alt. 1: PUCCH carrier switching is based dynamic indication in DCI**
* **Alt. 2B: PUCCH carrier switching is based on certain (semi-static) rules**
* **Alt. 2C: PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells**
* Note: In above alternatives, it is assumed that HARQ-ACK corresponding to PDSCH received on a Pcell/PScell or an Scell in a PUCCH group, can be sent on a PUCCH onan Scellalso instead ofonly onPcell/PScell/PUCCH-SCellin the same PUCCH group, as opposed to Rel-16 where HARQ-ACK corresponding to PDSCH received on a Pcell/PScell or an Scell in a PUCCH group can only be sent on Pcell/PScell/PUCCH-SCell in the same PUCCH group.

***Note: Realistic deployment scenarios including TDD configurations should be considered for the study***Agreement: Support PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH and semi-static configuration * Details are FFS (including applicability of dynamic and/or semi-static means)
* Aim for minimum specification impact
* Dynamic indication and/or semi-static configuration are subject to separate UE capabilities
* The semi-static PUCCH carrier switching configuration operation is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells and supports PUCCH carrier switching across cells with different numerologies.
	+ FFS whether additional rules are needed to support PUCCH carrier switching across cells with different numerologies
* FFS the maximum number of PUCCH cells
* FFS whether and how to support joint operation of dynamic and semi-static carrier switching for a UE
* FFS whether and how to support joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral

Agreement: For PUCCH carrier switching, the PUCCH resource configuration is per UL BWP (i.e. per candidate cell and UL BWP of that specific candidate cell). Agreement: For PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH (i.e. Alt. 1), the PDSCH to HARQ-ACK offset k1 is interpreted based on the numerology of the dynamically indicated target PUCCH cell. |

* 1. Summary of companies input in their contributions

**Generic for PUCCH carrier switching:**

**Interaction with SPS HARQ-ACK deferral:**

* **Support:** Huawei/HiSi [1], Ericsson [4], CATT [9], NEC [12] (for dynamic indication)
* **Not support:** OPPO [14], ETRI [19]
* **Details:**
	+ UE checks validity on the associated target carrier based on the PUCCH carrier switching pattern: Huawei/HiSi [1] – **No:** First apply deferral on PCell and then apply PUCCH carrier switching pattern: Panasonic [10]
	+ Perform PUCCH carrier switching first and then check the SPS HARQ-ACK deferral on the target PUCCH carrier: Ericsson [4], CATT [9], NEC [12] (?)
		- ‘slot\_offset’ pattern configured can be used also for SPS deferral: Ericsson [4]
	+ Stop the SPS HARQ-ACK deferral search stops as soon as dynamic indication of PUCCH carrier switching is received: Qualcomm [16]

**Limitation on maximum number of PUCCH cells within a PUCCH cell group:**

* 2 (PCell & 1 SCell, 1+1): Samsung [8], CATT [9], OPPO [14], Apple [23]
* 4 (in total, 3+1): Nokia/NSB [3]
* RRC configurable: FGI/APT [15], ETRI [19]
* No limitation needed: FGI/APT [15]

**List of candidate cells:**

* Based on a configured set of candidate carries (using carrier indexing) per cell group: Huawei/HiSi [1], Nokia/NSB [3]

**TPC operation for PUCCH cells:**

* Support separate TPC loops per PUCCH cell: Nokia/NSB [3], Qualcomm [16]
* Support separate P0 / TPC configuration per PUCCH cell: Qualcomm [16], Mediatek [20]
* Support individual TPC command starting points within DCI format 2\_2 for each PUCCH candidate: Nokia/NSB [3]
* Support accumulating closed loop power control commands only within the same target cell by reusing Rel-15 procedure: Qualcomm [16], Nokia/NSB [3], Mediatek [20]
	+ For dynamic indication, the TPC command in the DCI scheduling the PUCCH only applies for the dynamically indicated PUCCH target cell: Nokia/NSB [3]
	+ For semi-static / time-domain pattern, the TPC command in the DCI scheduling the PUCCH only applies for the determined PUCCH target (using the time-domain pattern): Nokia/NSB [3]

**PUCCH spatial relation update:**

* Support to use MAC-CE to signal PUCCH spatial relation on Scell(s) with PUCCH carrier switch: Qualcomm [16]

**Other:**

* Dynamic and semi-static PUCCH carrier switching should be configured and enabled for dynamic scheduling and SPS separately: Panasonic [10]
* Study and decide if /how to support joint operation of PUCCH carrier switch, parallel PUCCH/PUSCH transmission, and intra-UE multiplexing: Qualcomm [16]
* Support for scheduled PUCCH: Mediatek [20]

**PUCCH carrier switching based on dynamic indication:**

**Carrier indication:**

* Based on a configured set of candidate carries (using carrier indexing) per cell group: Huawei/HiSi [1], Nokia/NSB [3] (list can also be used for semi-static switching / time-domain pattern), Ericsson [4] (‘subset’?)
* **Introduce a new field in the DCI scheduling PDSCH (e.g. DCI formats 1\_1 & 1\_2) (9):** Huawei/HiSi [1], vivo [2], Nokia/NSB [3], Ericsson [4], Samsung [8], LGE [18], Mediatek [20], DoCoMo [26], CAICT [29]
	+ Bit-field size can be individually configured for DCI formats 1\_1 & 1\_2: Nokia/NSB [3] – No, size determined by the largest PUCCH carrier set across all PUCCH groups: Ericsson [4][
	+ Applicable to DG PDSCH, SPS PDSCH, SPS Release and triggered PUCCH for Type 3 CB: Ericsson [4] – **No:** for SPS dynamic carrier indication is not applicable (ignore in the activation DCI): LGE [18], DoCoMo [26]
	+ For DCI format 1\_0, 1bit from HPN or RV field could be used: Samsung [8]
* **PRI is used to instruct PUCCH carrier switching** (**4**) from a new configured PUCCH resource set, which can include PUCCH resources of different UL CCs: ZTE [6], Panasonic [10], LGE [18], Intel [21]
	+ PRI field size can be extended: Panasonic [10], Intel [21] – No / questionable: LGE [18]

**Multiplexing of DG HARQ (with dynamic indication), SPS-HARQ, SR and CSI**

* **Multiplex at least HARQ-ACK from PCell / PScell on the dynamically indicated target PUCCH cell if PUCCH slot or PUCCH resource on PCell/PScell overlap with dynamically indicated PUCCH slot or PUCCH resource on the target cell (7):** vivo [2], Nokia/NSB [3], Ericsson [4], CATT [9], NEC [12], DoCoMo [26], CAICT [29]
	+ **Alt. 1 PUCCH resources should be overlapping:** Nokia/NSB [3], NEC [12]
	+ **Alt. 2 PUCCH slots overlapping, PUCCH resources do not need to be overlapping:** vivo [2], CATT [9], DoCoMo [26], CAICT [29]
	+ **Additional details:**
		- Alternatively, a different PUCCH cell(s) may be configured / indicated: vivo [2]
		- Exception is SPS-HARQ together with CSI: Ericsson [4]
		- For mixed SCS, the smallest SCS can be used as the reference slot to determine the overlapping slots CATT [9]
* **HARQ-ACK transmission configured or scheduled for more than one Pcell PUCCH slot overlapping with the indicated PUCCH on Scell (e.g. for mixed SCS)**
	+ is considered as an error case: Nokia/NSB [3]
	+ multiplex both SPS HARQ to Scell PUCCH: DoCoMo
* **Pcell PUCCH with HARQ-ACK overlapping with Scell PUCCHs in multiple Scell slots (e.g. of higher SCS)**
	+ is considered as an error case: Nokia/NSB [3]
	+ multiplex on the first overlapping Scell slot: DoCoMo [26]
* **Limited to SR and SPS-HARQ only (no CSI):** Nokia/NSB [3], Intel [21] – support also CSI: Ericsson [4]
* **UE does not expect overlapping PUCCHs with dynamic indication on more than one carrier:** Ericsson [4], Interdigital [22], DoCoMo [26]
* **When a slot of a first cell overlaps with one or more slots of a second cell, a UE does not expect to transmit PUCCH in both the slot of the first cell and in any of the one or more slots of the second cell:** Samsung [8]

**HARQ codebook construction:**

* Apply the K1 set configured of the indicated carrier: Huawei/HiSi [1]
* HARQ-ACKs with same priority index pointed to the same slot/sub-slot on the same carrier will be constructed as one codebook: Huawei/HiSi [1]
* For Type 1 CB, the UE is not expected to be configured with non-aligned PUCCH slots and different k1 sets across all PUCCH candidate cells: Nokia/NSB [3] – FFS Type 1 CB construction: NEC [12]
* For Type 2 CB, the Rel-16 mechanism for HARQ-ACK codebook construction can be re-used: Nokia/NSB [3]
* Append HARQ-ACK codebooks on other cells to the original Type 1 or Type 2 CB on the dynamically indicated PUCCH carrier / PUCCH slot: DoCoMo [26]

**Out-of-order issues:**

* OoO rule between the carriers with PDSCH transmission and the carrier with PUCCH transmission should be applied based on the largest SCS: Huawei/HiSi [1]
* Out-of-order HARQ-ACK remains forbidden for non-mTRP scenarios with PUCCH carrier switching: Apple [23], Xiaomi [27]
* Out-of-order triggering is not supported: Xiaomi [27]

**K1 enhancements:**

* Configure additional k1 slot offset (for larger SCS cells): Panasonic [10]

**Other:**

* Guarantee by configuration, that the bit-width of PRI and PDSCH-to-HARQ\_feedback timing indicator is not ambiguous depending on the target cell: China Telecom [11]
* Support for configured SPS HARQ-ACK PUCCH: Mediatek [20]
* Nested PUCCH symbols across CCs are not allowed for PUCCH carrier switching: Apple [23]
* PUCCH switching for SPS HARQ-ACK is achieved by dynamic PUSCH scheduling in another cell: CAICT [29]

**PUCCH carrier switching based on semi-static configuration / time-domain pattern:**

**Reference numerology / cell:**

* **PCell / PSCell / PUCCH-SCell is reference cell (defining granularity of timing pattern and K1 interpretation) (6):** Huawei/HiSi [1], Nokia/NSB [3], Ericsson [4], Qualcomm [16], CMCC [17] (?), DoCoMo [26]
	+ PCell/PScell defines the reference slot, slot number of Scells is calculated according to *slot offset configuration given by* $N\_{slot, offset}^{CA}$: CMCC [17]
* **Reference numerology configured by RRC (2):** vivo [2] (and SCS\_ref needs to be ≤ any SCS of any configured UL bandwidth part), Mediatek [20]
* **Reference carrier configured by RRC (also used for K1 Interpretation) (1):** ZTE [6]
* **Reference numerology is the smaller/smallest SCS (2):** Samsung [8], CATT [9], China Telecom [11], CAICT [29] (of all BWPs)
* **Reference numerology is the largest SCS (1):** NEC [12]

**K1 & PRI interpretation and semi-static PUCCH resource usage:**

* **K1 interpretation on the reference cell to define the PUCCH target cell (7):** Huawei/HiSi [1], Nokia/NSB [3], Ericsson [4], ZTE [6], Samsung [8], China Telecom [11] (PCell, reference numerology for pattern could be different), LGE [19] (PCell/SPCell)
* **PRI interpretation on the PUCCH target cell (5):** Nokia/NSB [3], ZTE [6], CATT [9], LGE [18], Apple [23] (?)
* **Semi-static PUCCH resource on target cell defined by PUCCH-config for the target cell:** CATT [9]

**Configuration details:**

* **Time-domain pattern configured per PUCCH cell group** (**3**): vivo [2], Nokia/NSB [3], Ericsson [4]
* **Individual K1 set configuration per PUCCH cell (1)**: vivo [2]
* **Based on a configured set of candidate carries (using carrier indexing) per cell group (2)**: Nokia/NSB [3] (list can also be used for dynamic indication), Ericsson [4] – use serving cell indexes directly: CMCC [17]
* **Time-domain pattern granularity is one slot of the reference cell / numerology using carrier indexing** (**6**): Nokia/NSB [3] (pattern length up to *maxNrofSlots*), Ericsson [4], NEC [12], CMCC [17] (pattern length $N\_{slot}^{frame,μ}$ of the Pcell/PScell), Mediatek [20], DoCoMo [26] (based on TDD configuration length)
* **Time domain pattern per PUCCH candidate carrier, bitmap length given by number of UL slots within the period** (**1**): ZTE [6]
* gNB to guarantee that the PUCCH carrier switching points are aligned with the PUCCH slot/subslot boundaries: Nokia/NSB [3], CATT [9]
* Time-domain pattern is based on a periodicity and a time duration (for it’s repetition): FGI/APT [15]
* More than one time-domain can be configured and indicated to be applied (allowing for faster switching between patterns): FGI/APT [15]

**Mixed numerology handling:**

* For shorter PUCCH slot length on the target PUCCH cell (than the reference cell / numerology), the PUCCH transmission is in
	+ the first PUCCH slot on the target cell overlapping with the PCell slot: Huawei/HiSi [1], Samsung [8], CATT [9], China Telecom [11], Qualcomm [16] (first ‘actual’slot), LGE [18] (first UL slot), DoCoMo [26]
	+ using k1\_relative within the PCell slot indicated using HARQ-feedback indicator in the DCI: Nokia/NSB [3]
	+ configured slot\_offset pattern to define which overlapping PUCCH slot: Ericsson [4] (i.e. time domain pattern contains ‘cell index’ & ‘slot\_offset’)
	+ configured slot-offset per PUCCH target cell (within overlapping PCell slot): Panasonic [10]
* For switching to longer PUCCH slot length on the target cell compared to PCell:
	+ gNB implementation takes care of that timelines are met for PUCCH transmission switching to Scell: Nokia/NSB [3]
	+ UE does not expect to be indicated for HARQ-ACK codebooks in more than one of the PCell slots overlapping with a single Scell slot configured for PUCCH transmission: Nokia/NSB [3], CATT [9] – **No -** multiplexing should be considered: China Telecom [11], DoCoMo [26] (needs to be clarified if allowed)
* Predefined rules on the PUCCH target cell selection: vivo [2]
	+ *Moderator comment*: If one cell is a reference cell in terms of time-domain pattern and K1 interpretation, there should not be any ambiguity on the PUCCH target cell – only for the mixed SCS case (more than one target PUCCH cell slot overlapping with a single PUCCH slot of the reference cell, some further handling needs to be discussed)!??
* No additional rules are needed for mixed SCS / different PUCCH slot lengths: OPPO [14]
* Same SCS operation should be given highest priority: Xiaomi [27]

**PUCCH repetition operation:**

* The target cell is determined for each PUCCH repetition individually: Huawei/HiSi [1]
* Further study: NEC [12], Qualcomm [16], ETRI [19]

**PUCCH carrier switching for SR and CSI:**

* **At least for SR:** vivo [2], Nokia/NSB [3]
* **For any PUCCH (incl. CSI):** Ericsson [4], Samsung [8], ETRI [19]

**HARQ-ACK codebook construction:**

* Type 1 CB uses the K1 set(s) configured for the reference cell / numerology: Nokia/NSB [3], CAICT [29]

**SFI utilization:**

* **Legacy semi-static SFI and dynamic SFI operation applies on the target PUCCH cell:** Apple [23]

**Other:**

* UE selects the PUCCH carrier based on the carrier index in case more than one PUCCH carrier are available: Interdigital [22]
	+ *Moderator question*: How could it happen that more than one PUCCH carrier would be indicated for a specific? Anyhow, wouldn’t it be better (if such cases really happen) to define a rule (so that the UE behavior is defined) or expect that gNB configuration would prevent such cases??

**Joint operation of dynamic indication and semi-static configuration:**

**General support for joint operation:**

* **Yes:** Huawei / HiSi [1], Ericsson [4] (incl. RRC state ‘dynamic & SS’), CATT [9], NEC [12] (slightly preferred)
* **No:** OPPO [14]
* **FFS:** Nokia/NSB [3] (first define the details of stand-alone operation)

**Details:**

* If the carrier is dynamically indicated, the dynamic indication applies. If the carrier cannot be dynamically indicated (e.g. using fallback DCI format 1\_0), the semi-static carrier switching applies: Huawei / HiSi [1], Nokia/NSB [3] (from principle point of view), Ericsson [4], Samsung [8], FGI/APT [15] (?)
* Conclude if dynamic PUCCH overriding is allowed if the UCI can be transmitted based on the RRC-based indication: Samsung [8]
* UE does not expect that the dynamically indicated target PUCCH cell is different from the PUCCH cell determined by switching pattern: CATT [9]
* Dedicated indication in DCI for switching between two schemes: Panasonic [10]
* The semi-static carrier switching is applied when the PUCCH transmission is not possible over the dynamic indicated carrier: Panasonic [10]
	1. 1st Round of Email discussions

The following agreement was made during the 1st GTW session:

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| **Agreement**Update the following RAN1#105-e agreement as: * RAN1#105-e Agreement: For PUCCH carrier switching, the PUCCH ~~resource~~ configuration (i.e. *pucch-Config / PUCCH-ConfigurationList*) is per UL BWP (i.e. per candidate cell and UL BWP of that specific candidate cell).
	+ FFS: CSI and SR
 |

**Generic for PUCCH carrier switching**

**Limitation on maximum number of PUCCH cells within a PUCCH cell group:**

In their TDocs, 4 companies indicated the support for a maximum of 2 PUCCH cells within PUCCH cell group, 1 company indicated a maximum of 4 PUCCH cells and 2 companies indicated, that the maximum number of cells should be RRC configurable.

The intention of the maximum number of cells is to enable the RRC signaling & PHYdesign to be able to accommodate the max. number of cells. Of course, even though e.g. the feature design would have a limitation of X cells by RRC configuration there could be a smaller number of cells Y<X configured for the PUCCH carrier switching operation.

Therefore, the moderator thinks that some limit which is not just RRC configurable will be needed to for the feature design. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.1: Do you agree with the moderator assessment, that for the design e.g. for RRC signaling a fixed maximum limit on the maximum number X of PUCCH cells per cell group will be needed?**

* ***Note:* The gNB can of course based on RRC configuration configure a smaller number of PUCCH cells X<Y.**
* **Supporting companies: Nokia/NSB,** …
* **Companies not supporting:** …

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| *Company* | *Comments* |
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**Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.2: If a fixed maximum limit on the maximum number X of PUCCH cells per cell group is defined:**

* **Alt. 1: X=2**
	+ **Supporting companies:** …
* **Alt. 2: X=4**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 3: X=? / Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 – X=? / other*  |
| Nokia, NSB | As discussed in our contribution, 4 cells should be sufficient but 2 cells seems to be too limiting.  |
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**TPC operation for PUCCH cells:**

3 companies raised the issue of independent TPC / TPC loops and suggested to operate independent TPC loops per PUCCH cell. This may include:

* Separate P0 / TPC configuration per PUCCH cell
	+ Note: This flexibility is already provided as *PUCCH-config* is per UL BWP of a PUCCH cell (see related discussions there)
* Accumulating closed loop power control commands only within the same target cell by reusing Rel-15 procedure
	+ For dynamic PUCC cell indication, the TPC command in the DCI scheduling the PUCCH only applies for the dynamically indicated PUCCH target cell
	+ For semi-static / time-domain pattern, the TPC command in the DCI scheduling the PUCCH only applies for the determined PUCCH target (using the time-domain pattern)
* Support separate TPC command indication using DCI format 2\_2 for the individual PUCCH cells (i.e. requiring configuration of individual TPC command starting points for each PUCCH cell within DCI format 2\_2)

**Please add your companies name directly to each of the separate points there , and provide your additional comments or alternatives in the table below.**

**Proposal 6.1: Support independent TPC per PUCCH cell including**

**• Separate P0 / TPC configuration per PUCCH cell**

* + Note: This flexibility is already provided as PUCCH-config is per UL BWP of a PUCCH cell
* **Accumulating closed loop power control commands only within the same target cell by reusing Rel-15 procedure, i.e.**
	+ For dynamic PUCCH cell indication, the TPC command in the DCI scheduling the PUCCH only applies for the dynamically indicated PUCCH target cell
	+ For semi-static / time-domain pattern, the TPC command in the DCI scheduling the PUCCH only applies for the determined PUCCH target (using the time-domain pattern)
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Separate TPC command indication using DCI format 2\_2 for the individual PUCCH cells**
	+ Note: this requires configuration of individual TPC command starting points for each PUCCH cell within DCI format 2\_2
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …

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| *Company* | *Comments*  |
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**Dynamic PUCCH cell indication**

**Target PUCCH cell indication**

On the **dynamic PUCCH carrier indication, 9 companies** indicated to include a **new, dedicated field in the DCI** to indicate the target PUCCH carrier, whereas **4 companies** suggest to **use the existing PRI field**, by having a mapping of a combination of target PUCCH carrier and PUCCH resource indication on the target PUCCH carrier to be indicated by the PRI field. Clearly, using PRI and having some need to have a combination of PUCCH resource index and PUCCH cell will complicate the RRC signaling design. As mentioned by some companies, having **a dedicated field will simplify the design**. Therefore, the following is proposed:

**Proposal 6.2: For PUCCH carrier switching based on dynamic indication in the DCI, introduce a new, dedicated DCI field for the DCI scheduling PDSCH to indicate the target PUCCH cell.**

* ***FFS: Bit-field width for DCI format 1\_1***
* **DCI field presence for DCI format 1\_2 is independently RRC configured**
	+ ***FFS: Bit-field width for DCI format 1\_2***
* ***FFS: If some bit(s) from existing bit fields could be used for DCI format 1\_0***

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

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| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
| Nokia/NSB | Support, and as discussed in our contribution the bit-field width could be RRC configured for DCI format 1\_1 and 1\_2 (individually).  |
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In the discussion by different companies, there are different views e.g. for SPS PDSCH if the dynamic PUCCH carrier indication applies or not. Therefore, the following question is brought forward to get feedback from different companies on the applicability of the dynamic cell indication. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.3: In addition to HARQ-Ack of PDSCH dynamically scheduled by a DCI indicating a PUCCH carrier, the dynamic target carrier indication also applies to:**

* **Alt. 1: applicable also to SPS PDSCH HARQ-ACK without associated DCI based on the indication in the activation DCI**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 2: applicable also to HARQ-ACK of the SPS Activation based on the indication in the activation DCI**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 3: applicable also to HARQ-ACK SPS Release based on the indication in the release DCI**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 4: applicable also to triggered PUCCH for Rel-16 Type 3 CB, Rel-17 enh. Type 3 CB of smaller size and Rel-17 one-shot triggering for HARQ-Ack retransmission based on the indication in the triggering DCI**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 5: applicable also for SP-CSI based on the dynamic indication in the activation DCI**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB,** …
* **Alt. 6: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 6 / other*  |
| Nokia/NSB | We support any HARQ-ACK in response to a DL assignment indicating the target carrier dynamically (i.e. Alt. 2, 3 and 4) – but think that it should not apply based on some activation command then semi-statically.  |
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3 companies mention, that the dynamic PUCCH cell indication should not be changed for a certain PUCCH slot – i.e. the gNB should always indicate the same PUCCH cell. The following proposal is brought forward:

**Proposal 6.3: UE does not expect overlapping PUCCHs with dynamic PUCCH cell indication on more than one carrier, i.e. gNB should only dynamically indicate a single PUCCH cell for a final PUCCH slot.**

* + **Supporting companies:** …
	+ **Companies not supporting:** …

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| *Company* | *Comments*  |
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**HARQ-ACK multiplexing between PCell/SPCell and target cell (incl. other UCI types)**

**Seven companies discuss the multiplexing for HARQ-ACK on PCell/PSCell** (e.g. for PDSCH scheduled by DCI format 1\_0) and that there should be multiplexing with the HARQ-ACK on the indicated PUCCH cell. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.4: For PUCCH carrier switching based on dynamic indication in the DCI, multiplex at least HARQ-ACK from PCell / PScell on the dynamically indicated target PUCCH cell**

* **Alt. 1: if PUCCH slot on PCell/PScell overlaps with dynamically indicated PUCCH slot on the target cell**
	+ **Supporting companies:** …
* **Alt. 2: if** **PUCCH resource on PCell/PScell overlaps with the dynamically indicated PUCCH resource on the target cell**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 3: other rules for HARQ-ACK**
	+ **Supporting companies:** …
* ***FFS: for other UCI types (i.e. SR & CSI)***

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| *Company* | *Comments or Alt. 3 / other*  |
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There had been slightly different opinions, if in addition to HARQ-ACK from PCell/PSCell also CSI and/or SR could be multiplexed on the dynamically indicated SCell. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.5: For dynamic PUCCH carrier indication, in addition to HARQ-Ack from PCell/PSCell, the following UCI types are supported to be multiplexed on the indicated PUCCH cell:**

* **Alt. 1: SR**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 2: P-CSI / SP-CSI**
	+ **Supporting companies:** …
	+ **Companies not supporting: Nokia/NSB** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 / other*  |
| Nokia, NSB | Super SR (for latency), but don’t see a need to dynamically move CSI to an alternative carrier. Motivation is HARQ latency, so it should not be an issue to find a valid slot for CSI on the PCell for CSI.  |
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**Semi-static PUCCH cell indication**

**Pattern definition**

On the **time-domain pattern for semi-static PUCCH switching** the following can be noted:

* **6 companies describe that a single time-domain pattern is configured**, where for each of the slots in the pattern the applicable PUCCH cell is indicated (using either cell ID or some carrier indexing of list of configured candidate carriers) – **whereas one company suggests a time domain pattern for each PUCCH cell**, where the time-pattern for each PUCCH cell is only a bit map of the UL slots within the pattern periodicity (i.e. UE would need to check several patterns to identify the target cell, gNB to prevent by configuration overlaps of the patterns).
* **3 companies** mentioned that the time-domain pattern should be **configured per PUCCH cell group**
* **3 companies** mention that the time-domain pattern length / periodicity, should be **aligned with TDD configuration (i.e. length of 10ms / 1 frame)**
* There are overall different opinions on the reference numerology or reference cell for the time domain pattern. Therefore, this would need to be decided separately.

Based on these observations the following is proposed. **Please add your companies name directly to each of the separate points there , and provide your additional comments or alternatives in the table below.**

**Proposal 6.4: For semi-static PUCCH carrier switching, the time-domain pattern configuration is based on the following properties:**

* **A single time-domain pattern is configured per PUCCH cell group**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **The granularity of the time-domain pattern is one slot of the reference numerology / reference cell**
	+ ***FFS definition of reference numerology / reference cell***
	+ **Supporting companies: Nokia/NSB**…
	+ **Companies not supporting:** …
* **The length of the time-domain pattern is one frame (i.e. 10ms)**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **The pattern defines for each slot of the reference numerology / reference cell the applicable PUCCH cell**
	+ ***FFS: if the indication in the time-domain pattern is directly using the serving cell index of the target PUCCH cell or if some additional list of PUCCH cells is configured (which could be used)***
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …

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| *Company* | *Comments*  |
| Nokia/NSB | Fully support the proposal. As also indicated in some other questions, we think we need a reference cell (and not just numerology) and the PCell could be a good choice for that.  |
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**K1 and PRI interpretation**

**On the k1 and PRI interpretation for semi-static PUCCH carrier switching:** Moreover, several companies mention the k1 value should be interpreted on the PCell or a reference cell to define the slot on the PCell/PSCell or reference cell which is then used together with the time-domain pattern (which may or may not have a different reference SCS as the PCell/PSCell or reference cell) to determine the target PUCCH cell. Moreover, a group of companies also mention that the PRI should be interpreted on the determined target PUCCH cell.

**Proposal 6.5: For semi-static PUCCH carrier switching, the PDSCH to HARQ-ACK offset k1 is interpreted based on the numerology and PUCCH configuration of a reference cell to be able to apply the time-domain PUCCH carrier switching pattern.**

* + ***FFS definition reference cell***

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

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| --- | --- |
| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
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**Proposal 6.6: For semi-static PUCCH carrier switching, the PUCCH resource indicator (PRI) is interpreted based on the PUCCH configuration of determined target PUCCH cell.**

**Please provide you input to the following two tables, first table your company name (for easier checking) and 2nd table for additional comments.**

|  |  |
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| Supporting companies | Nokia/NSB,  |
| Objecting companies |  |

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| *Company* | *Comments*  |
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**PUCCH carrier switching operation alternatives:**

There had been different interpretations of how to determine the PUCCH cell using the configured time-domain pattern and the k1 value:

* **Alt. 1:** **Only a reference cell is defined:** The numerology of the reference cell is used to interpret the time-domain pattern for PUCCH cell switching and the reference cell is used to interpret the PDSCH to HARQ-ACK offset k1
	+ With this approach, the UE after determining the PUCCH slot on the reference cell using k1 directly can look-up in the time-domain pattern to determine the PUCCH cell in a second step
		- See e.g. Huawei/HiSi [1] assuming the PCell as reference cell
	+ The reference cell could be the PCell/PSCell or some RRC configured PUCCH cell (incl. potential configuration restrictions having the smallest or largest SCS of the PUCCH cells)
* **Alt. 2: A reference numerology and a reference cell (of potentially different numerology) is defined:** The reference numerology is used to interpret the time-domain pattern for PUCCH carrier switching, whereas the reference cell (e.g. the PCell/PSCell) is used to interpret the PDSCH to HARQ-ACK offset k1
	+ With this approach, the UE first determines the PUCCH slot on the reference cell (e**.**g. PCell/PSCell). In a second step, the UE determines the overlapping slot of the reference numerology with the PUCCH slot on the reference cell. In a third step, the UE determines the PUCCH cell based on the time-domain pattern and the overlapping slot of the reference numerology
		- See, e.g. description by China Telecom [11]

**Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.6: The semi-static PUCCH carrier switching should be based on:**

* **Alt. 1: a reference cell used for the time-domain pattern and k1 interpretation**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: a reference numerology used for the time-domain pattern interpretation and a reference cell is used for the PDSCH to HARQ-ACK offset k1 interpretation**
	+ **Supporting companies:** …
* **Alt. 3: other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 / other*  |
| Nokia/NSB | We don’t see any advantage to define some reference numerology, as this will just complicate the operation. Having a reference cell (preferably the PCell) seems to be better suited.  |
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**Reference cell definition**

As it is clear, that at least a reference cell is needed for the k1 interpretation, let’s get feedback on how the reference cell is defined. Please note, that if there is separate k1 configuration per PUCCH cell it is not sufficient to say ‘PUCCH cell’ of smallest or largest SCS, as there may be more than one PUCCH cell of the same smallest or largest SCS with different K1 sets configured. **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.7: For semi-static PUCCH carrier switching, the reference cell is defined as:**

* **Alt. 1: the PCell / PScell**
	+ **Supporting companies: Nokia/NSB,** …
* **Alt. 2: an RRC configured PUCCH cell of any numerology**
	+ **Supporting companies:** …
* **Alt. 3: an RRC configured PUCCH cell having the smallest SCS among PUCCH cells**
	+ **Supporting companies:** …
* **Alt. 4: an RRC configured PUCCH cell having the largest SCS among PUCCH cells**
	+ **Supporting companies:** …
* **Alt. 5: other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 5 / other*  |
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**Support for other UCI types**

There had been slightly different opinions, if in addition to HARQ-ACK from PCell/PSCell also CSI and/or SR could be multiplexed on the semi-statically configured PUCCH cell (other than PCell/PSCell). **Please add your companies name directly to the Alternatives in the question, and provide your additional comments or alternatives in the table below.**

**Question 6.8: For semi-static PUCCH carrier switching, in addition to HARQ-Ack from PCell/PSCell the following UCI types are supported to be multiplexed on the semi-statically determined target PUCCH cell:**

* **Alt. 1: SR**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 2: P-CSI / SP-CSI**
	+ **Supporting companies: Nokia/NSB,** …
	+ **Companies not supporting:** …
* **Alt. 3: Other**
	+ **Supporting companies:** …

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| *Company* | *Comments or Alt. 3 / other*  |
| Nokia, NSB | As the time-domain pattern is fixed and RRC configured, there is no need to prevent SR and CSI operation (in contrast to dynamic indication, where we think only SR should be supported).  |
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# Other proposals (not directly related to Sec. 2-6 / agreed Rel-17 HARQ enhancements)

* Increase the number of reserved REs for HARQ-ACK on PUSCH: Samsung [8] (see details in Sec. 2.7 of [8])
* Remove duplicated HARQ-ACK information from the Type-1 HARQ-ACK codebook for intra slot PDSCH repetition: Samsung [8] (see details in Sec. 2.8 of [8])
* The HARQ-ACK timing indicator counts only slots with PUCCH resources: Samsung [8] (see details in Sec. 2.9 of [8])

# References

1. R1-2106490 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon
2. R1-2106586 HARQ-ACK enhancements for Rel-17 URLLC vivo
3. R1-2106636 HARQ-ACK Feedback Enhancements for URLLC/IIoT Nokia, Nokia Shanghai Bell
4. R1-2106678 HARQ-ACK Enhancements for IIoT/URLLC Ericsson
5. R1-2106697 Discussion on HARQ-ACK feedback enhancements for Rel-17 URLLC Spreadtrum Communications
6. R1-2106734 Discussion on HARQ-ACK enhancements for eURLLC ZTE
7. R1-2106801 Considerations on HARQ-ACK enhancements for URLLC Sony
8. R1-2106879 On HARQ-ACK reporting enhancements Samsung
9. R1-2106962 UE feedback enhancements for HARQ-ACK CATT
10. R1-2107025 Discussion on UE feedback enhancements for HARQ-ACK Panasonic
11. R1-2107133 Discussion on UE feedback enhancements for HARQ-ACK China Telecom
12. R1-2107156 UE feedback enhancements for HARQ-ACK NEC
13. R1-2107180 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility
14. R1-2107272 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO
15. R1-2107296 Discussion on UE feedback enhancements for HARQ-ACK FGI, Asia Pacific Telecom
16. R1-2107336 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated
17. R1-2107397 Discussion on UE feeback enhancements for HARQ-ACK CMCC
18. R1-2107443 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics
19. R1-2107472 UE feedback enhancements for HARQ-ACK ETRI
20. R1-2107491 On UE feedback enhancements for HARQ-ACK MediaTek Inc.
21. R1-2107583 Design aspects for the agreed HARQ feedback enhancements Intel Corporation
22. R1-2107639 HARQ enhancements for IIoT and URLLC InterDigital, Inc.
23. R1-2107732 HARQ Feedback Enhancements for URLLC Apple
24. R1-2107791 UE feedback enhancements for HARQ-ACK Sharp
25. R1-2107833 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.
26. R1-2107851 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
27. R1-2107917 UE feedback enhancements for HARQ-ACK Xiaomi
28. R1-2108152 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.
29. R1-2108162 UE feedback enhancements for HARQ-ACK CAICT

# Appendix A: RAN1 agreements on HARQ-ACK feedback enhancements for NR Rel-17 URLLC/IIoT

**RAN1#102-e (Aug. 2020)**

Agreements:

Support Rel-17 enhancements to avoid SPS HARQ-ACK dropping for TDD due to PUCCH collision with at least one DL or flexible symbol.

* This topic is to be considered as high priority
* FFS detailed solution(s)

Agreements:

* Simultaneous PUSCH / PUCCH within a cell group (of Sec. 6.13 of R1-2007216) and enhanced (sub-slot) HARQ-ACK multiplexing on PUSCH (of Sec. 4.3 of R1-2007216) can be further discussed as part of AI 8.3.3 in this WI (but not as part of AI 8.3.1.1).

Agreements:

Study further at least the following schemes:

* SPS HARQ skipping for ‘skipped’ SPS PDSCH
* PUCCH repetition enhancements (at least for HARQ-ACK), e.g., sub-slot based, etc.
* Retransmission of cancelled HARQ
* SPS HARQ payload size reduction and / or skipping for ‘non-skipped’SPS PDSCH
* Type 1 HARQ codebook based on sub-slot PUCCH config
* PUCCH carrier switching for HARQ feedback

**RAN1#103-e (Oct/Nov. 2020)**

Agreements: To address the issue of SPS HARQ-ACK dropping for TDD systems, focus on the following two options:

* Option 1: Deferring HARQ-ACK until a next (e.g., first) available PUCCH
	+ FFS: Details including the definition of a next (e.g, first) available PUCCH, CB construction / multiplexing
* Option 2: Dynamic triggering of a one-shot / Type-3 CB type of re-transmission
	+ FFS: Details on triggering and/or CB construction (incl. potential Type-3 CB optimizations) / multiplexing

**Agreements: In the studies on PUCCH carrier switching for HARQ-ACK, PUCCH carrier switching for different cells operated is considered only for cells that are part of the active UL CA configuration.**

**Agreements: For the studies on SPS HARQ skipping for skipped SPS PDSCH, the further discussions should focus on the following reduced sets methods:**

* **‘NACK skipping’ for (skipped) SPS PDSCH (Alt. 1)**
	+ **FFS: details including at least when to skip the HARQ-ACK as well as NACK skipping configuration details (per SPS or group of SPS configurations etc.)**
	+ Note: this alternative assumes inherently no identification of a skipped SPS PDSCH by the UE
* **Dynamic indication of skipped SPS PDSCH occasions (Alt. 3)**
	+ **FFS: details including dynamic indication methods such as e.g. DCI, MAC CE, specific DM-RS instead of SPS DM-RS, …**

**Agreements:** For the studies on SPS HARQ payload size reduction (of non-skipped SPS PDSCH), the further discussions should focus on the following reduced sets of methods:

1. ACK skipping (NACK-only) (Alt. 1)
	1. FFS: Details
2. NACK skipping (ACK-only) (Alt. 2)
	1. FFS: Details
3. HARQ bundling / compression (Alt. 3)
	1. FFS: Details including HARQ bundling / compression window, bundling / compression technique
4. HARQ-ACK disabling /skipping for certain SPS configurations (Alt. 4)
	1. The skipping / disabling is higher-layer configured per SPS configuration
	2. FFS: HARQ-ACK skipping behaviour for Type 1 CB

**RAN#89 (Dec. 2020) – see agreed conclusion from** [RP-202872](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Docs/RP-202872.zip)

**RAN conclusion on IIoT scope:**

* For handling of the PUCCH repetitions it is proposed to proceed as follows:
1. RAN1 to continue discussion on PUCCH repetition, whether to specify or not, in the IIoT/URLLC WI for single TRP.
	1. The following items are not within scope of the continued discussions in the IIoT/URLLC WI:
		1. DMRS-less PUCCH with UCI payload up to 11 bits
		2. PUSCH-repetition-Type-B like PUCCH repetition
		3. DMRS bundling across PUCCH repetitions
2. PUCCH repetition issues with multi-TRP to be handled in Fe-MIMO WI.
* For the UE CSI/HARQ-ACK feedback enhancements in the IIoT/URLLC WI, RAN1 work to continue the discussions. Status to be checked in March if any RAN level guidance needed.
	+ RAN1 to continue discussion on A-CSI on PUCCH, whether to specify or not.

**RAN1#104-e (Jan/Feb. 2021)**

Agreements:

* Support deferring SPS HARQ-ACK dropped due to TDD specific collisions until a next available PUCCH in Rel-17 based on semi-static configuration of slot format
	+ FFS: Details (including possible conditions for such a deferring, whether or not to consider semi-statically configured flexible symbols for PUCCH availability, etc.)
	+ Aim for minimal standardization efforts and UE complexity in implementation

Agreements:

Further down-select between the following two options for SPS HARQ-ACK deferral:

* Option 1: Joint RRC configuration of the SPS HARQ-ACK deferral per PUCCH cell group
	+ *Note: any SPS HARQ-ACK within a PUCCH cell group in principle is subject to deferral*
* Option 2: The SPS HARQ-ACK deferral is configured per SPS configuration
	+ *Note: part of sps-config, only HARQ-ACK of SPS PDSCH configurations configured for deferral is in principle subject to deferral*

Agreements: Support sub-slot based PUCCH repetition for HARQ-ACK based on the Rel-16 PUCCH procedure for slot-based PUCCH applied to sub-slot based PUCCH

* Note: the intention is to take the Rel-16 slot-based PUCCH by replacing with “sub-slot” appropriately, without further optimization unless necessary
* FFS whether or not there is any restriction for the applicability of sub-slot based PUCCH repetition for HARQ-ACK
* Dynamic repetition indication is supported also for sub-slot based PUCCH in Rel-17
	+ FFS: if the method to be specified in Cov. Enh WI for slot-based PUCCH repetition can be directly applied to sub-slot PUCCH or if changes are needed

Agreements: Support PUCCH repetition for PUCCH formats 0 and 2 at least for sub-slot based PUCCH repetition.

* FFS: Support for slot-based PUCCH repetition

Agreements: Rel-16 UCI multiplexing  / PUCCH overriding rules are reused for deferred SPS HARQ-ACK in the target slot, if applicable.

Agreements: For SPS HARQ-ACK, the deferral from the initial slot/sub-slot determined by *k1* in the activation DCI to the target slot/sub-slot determined by *k1*+ *k1def*, the UE will check the validity of a target slot/sub-slot evaluating from one slot/sub-slot to the next sub/sub-slot (i.e. in principle *k1def* granularity is 1 slot/sub-slot)

* FFS: if there is a limit on the minimum deferral considered the required UE processing (*k1def* ≥0)
* FFS: if there is a limit on the maximum deferral

Agreements: For SPS HARQ-ACK deferral, for the determination of valid symbols in the initial slot/sub-slot a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as ‘invalid’ or ‘no symbols for UL transmission’.

Agreements: **For further study on** **whether and how to support** **PUCCH carrier switching** **in a PUCCH group, focus on the following three alternatives:**

* **Alt. 1: PUCCH carrier switching is based dynamic indication in DCI**
* **Alt. 2B: PUCCH carrier switching is based on certain (semi-static) rules**
* **Alt. 2C: PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells**
* Note: In above alternatives, it is assumed that HARQ-ACK corresponding to PDSCH received on a Pcell/PScell or an Scell in a PUCCH group, can be sent on a PUCCH onan Scellalso instead ofonly onPcell/PScell/PUCCH-SCellin the same PUCCH group, as opposed to Rel-16 where HARQ-ACK corresponding to PDSCH received on a Pcell/PScell or an Scell in a PUCCH group can only be sent on Pcell/PScell/PUCCH-SCell in the same PUCCH group.
* ***Note: Realistic deployment scenarios including TDD configurations should be considered for the study***

**RAN1#104b-e (April 2021)**

Agreements: For SPS HARQ-ACK deferral, for the determination of valid symbols in the target slot/sub-slot a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as ‘invalid’ or ‘no symbols for UL transmission’.

Agreements: For SPS HARQ-ACK deferral, support a limit on the maximum deferral of SPS HARQ in terms of *k1def* or *k1*+ *k1def*

* + FFS: limitation given by a maximum value of *k1def* or a maximum of *k1eff* =*k1*+ *k1def*
	+ FFS how the limitation is determined (e.g. by K1 set(s) or RRC configured limit)

Agreements: For SPS HARQ-ACK deferral, there is no lower limit defined for *k1def*

**Conclusion:**

No support for dynamic indication of skipped SPS PDSCH occasions in Rel-17 as part of this WI.

Agreement: Restrict the further discussions on the initial slot handling for SPS HARQ-ACK deferral to the identified alternatives Alt. 1, Alt. 1A and 2.

Agreement: For SPS HARQ-ACK deferral, the limit on the maximum deferral of SPS HARQ is defined in terms of *k1eff =k1*+ *k1def.*

Working assumption: To handle the collision for the same HARQ process due to deferred SPS HARQ-ACK the following behaviour is to be specified:

* In case the UE receives PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.

Agreement: For SPS HARQ-ACK deferral, the initial HARQ-ACK transmission occasion is considered to determine the out-of-order HARQ condition

Agreement: Support Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration in Rel-17.

* The properties of the Type-1 HARQ-ACK codebook for sub-slot PUCCH at least includes that a PDSCH TDRA is associated with a UL /PUCCH sub-slot if the end of the PDSCH overlaps with the associated sub-slot determined by a k1 in the set of sub-slot timing values K1.
* FFS: whether the PDSCH TDRA grouping is performed per DL slot or sub-slot
	+ Decide between PDSCH TDRA grouping per DL slot and sub-slot during RAN1#105-e

**RAN1#105-e (May 2021)**

Working Assumption: For at least HARQ-ACK re-transmission:

* Support at least one enhanced Type 3 HARQ-ACK CB with smaller size (compared to Rel-16) in Rel-17
	+ *Definition of enhanced Type 3 CB:*
		- *The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook at least determined by RRC configuration*
		- *The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)*
* Support one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB (i.e. Alt. 3) in Rel-17
	+ *Details are FFS*
* Enhanced Type 3 HARQ-ACK CB and/or one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB are subject to separate UE capabilities

Agreement: Support PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH and semi-static configuration

* Details are FFS (including applicability of dynamic and/or semi-static means)
* Aim for minimum specification impact
* Dynamic indication and/or semi-static configuration are subject to separate UE capabilities
* The semi-static PUCCH carrier switching configuration operation is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells and supports PUCCH carrier switching across cells with different numerologies.
	+ FFS whether additional rules are needed to support PUCCH carrier switching across cells with different numerologies
* FFS the maximum number of PUCCH cells
* FFS whether and how to support joint operation of dynamic and semi-static carrier switching for a UE
* FFS whether and how to support joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral

Agreement: For PUCCH carrier switching, the PUCCH resource configuration is per UL BWP (i.e. per candidate cell and UL BWP of that specific candidate cell).

Agreement: For PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH (i.e. Alt. 1), the PDSCH to HARQ-ACK offset k1 is interpreted based on the numerology of the dynamically indicated target PUCCH cell.

**RAN#92-e (June 2021) – *see section 3.2 of*** [***RP-211569***](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_92e/Docs/RP-211569.zip)

During the GTW session the following recommendations with further revisions were endorsed.

* **……**
* **Revised Recommendation2**: Provide the following RAN guidance on *HARQ-ACK enhancement [RAN1]*
	+ No further discussions on SPS HARQ-ACK skipping and size reduction~~bundling/compression~~.

**RAN1#106-e (Aug. 2021)**

**Agreement**

The SPS HARQ-ACK deferral is enabled per SPS configuration

* Note: part of sps-config, only HARQ-ACK of SPS PDSCH configurations enabled for deferral is in principle subject to deferral

Agreement

Definition of when to defer from the initial slot:

Alt1: Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid

**Agreement**

Update the following RAN1#105-e agreement as:

* RAN1#105-e Agreement: For PUCCH carrier switching, the PUCCH ~~resource~~ configuration (i.e. *pucch-Config / PUCCH-ConfigurationList*) is per UL BWP (i.e. per candidate cell and UL BWP of that specific candidate cell).
	+ FFS: CSI and SR

# Appendix B: Summary of companies’ proposals

In here, the proposals and some example figures are collected for easier referencing.

### R1-2106490 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon

***Observation 1: For sub-slot based Type 1 codebook, per slot based grouping has limited changes for codebook generation procedure on top of the legacy specification.***

***Observation 2: For sub-slot based Type 1 codebook, per slot based grouping can reduce non-negligible bit number of HARQ-ACK feedback compared to per sub-slot based grouping.***

**Proposal 1: *The maximum deferral k1*+ *k1def of the SPS HARQ-ACK should be the maximum k1 value in dl-DataToUL-ACK.***

**Proposal 2：*Down select between Alt.1 and Alt.1A as the SPS deferral condition:***

* ***Alt. 1: “If SPS HARQ-ACK is multiplexed with any other UCI / dynamic PUCCH resource then it cannot be deferred!”***
* ***Alt. 1A “Defer SPS HARQ even if multiplexing & transmission based on PRI in initial slot would be possible”.***

**Proposal 3: *For codebook construction for deferred SPS HARQ-ACK in the target slot,***

* ***For Type 1 CB, deferred SPS HARQ-ACK with k1+ k1def included in the K1 set can be mapped in the Type 1 CB following the Rel-15/Rel-16 rule, while those with k1+ k1def not included in the K1 set can be appended.***
* ***For SPS only CB and type 2 CB, Rel-16 rules can be reused.***

**Proposal 4: *For a candidate target slot/sub-slot, if the resulting PUCCH resource is unavailable, both the SPS HARQ-ACK(s) which have been deferred to this slot/sub-slot and the SPS HARQ-ACK originally pointed to this slot/sub-slot should be deferred in together to the next candidate slot/sub-slot.***

**Proposal 5：*Support TDRA grouping performed per slot for sub-slot based*** ***Type 1 CB,***

* ***Step 1: Determine DL slots consisting of DL sub-slots associated to the determined UL sub-slot***
* ***Step 2: In each determined DL slot, prune the PDSCH SLIVs whose ending symbols overlap with DL sub-slots that not associated to the determined UL sub-slot based on K1 set.***
* ***Step 3: Perform per slot SLIV splitting among the remaining SLIVs for each slot to generate the TDRA groups, each group of which is associated with the HARQ-ACK bit field.***

**Proposal 6: *Confirm the WA in the Coverage Enhancements WI where the repetition factor is dynamically indicated by the PRI field, and the PUCCH repetition factor is configured per PUCCH resource.***

**Proposal 7: *Support slot-based PUCCH repetition for PUCCH Format 0 and Format 2.***

**Proposal 8: *For dynamic indicating the target PUCCH carrier, consider to introduce a new field in DCI and a configured carrier set consisting of candidate carrier indices.***

**Proposal 9: *For*** ***interpreting the PDSCH to HARQ-ACK offset k1 under dynamic carrier indication, the K1 set configured for the indicated carrier should be used.***

**Proposal 10: *For the codebook construction in case of PUCCH carrier switching, HARQ-ACKs with same priority index pointed to the same slot/sub-slot on the same carrier will be constructed as one codebook.***

**Proposal 11: *For PUCCH carrier switching across different numerologies, the OoO rule between the carriers with PDSCH transmission and the carrier with PUCCH transmission should be applied based on the largest SCS.***

**Proposal 12: *For configuration of the RRC configured PUCCH carrier timing pattern,***

* ***The reference numerology is the SCS of PCell and the granularity of the timing pattern is based on the SCS of PCell.***
* ***K1 interpretation is based on K1 set configured for PCell.***

**Proposal 13: *For PUCCH carrier switching across different numerologies based on RRC configured timing pattern, the target slot on the target carrier for PUCCH transmission is the first available slot overlapping with the reference slot of the PUCCH carrier timing pattern.***

**Proposal 14: *For PUCCH carrier switching, consider to determine the target carrier for each PUCCH repetition individually based on the availability carrier of the slot.***

**Proposal 15: *Support joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral.***

* ***For each candidate target slot/sub-slot, the UE will check its validity on its associated target carrier based on the PUCCH carrier switching pattern, until an available PUCCH resource is identified to carry the deferred SPS HARQ-ACK.***

**Proposal 16: *For dynamic HARQ-ACK scheduled by fallback DCI with DCI format 1\_0,***

* ***If semi-static carrier switching is configured, it will be transmitted based on semi-static carrier switching.***
* ***Otherwise, it should be transmitted on PCell.***

**Proposal 17：*If supporting Type 3 CB(s) with smaller size (compared to Rel-16) in Rel-17, the codebook size is determined only by RRC configuration, i.e. no any additional dynamic signaling involved.***

### R1-2106586 HARQ-ACK enhancements for Rel-17 URLLC vivo

***Proposal 1: The SPS HARQ-ACK deferral is configured per SPS configuration.***

***Proposal 2: For the conditions for SPS HARQ-ACK deferral from/within the initial slot/sub-slot, support Alt.1, i.e., if SPS HARQ-ACK is multiplexed with any other UCI/dynamic PUCCH resource then it cannot be deferred.***

***Proposal 3: multi-CSI-PUCCH-ResourceList, as well as pucch-CSI-ResourceList, is supported as candidate PUCCH resource(s) when performing SPS HARQ-ACK multiplexing with CSI.***

***Proposal 4: The PUCCH resource(s) for the deferred SPS HARQ-ACK should re-use the PUCCH resource(s) for HARQ-ACK corresponding to DL dynamic scheduling configured in one or more PUCCH resource sets and the PUCCH resource(s) configured for SR and/or CSI, subject to UCI multiplexing between SPS HARQ-ACK and other UCI(s), as well as the PUCCH resource(s) configured for SPS HARQ-ACK transmissions in Rel-15/16.***

***Proposal 5: In a potential target slot/sub-slot, the deferral decision takes the UCI multiplexing into account, and the same logic applied to the initial slot/sub-slot should be applied to the target slot/sub-slot.***

***Proposal 6:*** ***It should be determined if there is any limitation for k1eff applied to deferred SPS HARQ-ACK, and regarding the limitation, following options could be considered:***

* ***Option 1: k1eff should not exceed the maximum K1 configured by high layer.***
* ***Option 2: k1eff should correspond to a candidate K1 in the K1 set configured by high layer.***

***Proposal 7:*** ***It should be discussed how to construct the HARQ-ACK codebook containing deferred SPS HARQ-ACK, and for Type-1 codebook the codebook construction is highly dependent on the determination of k1eff for deferred SPS HARQ-ACK.***

***Proposal 8:*** ***Support including priority indication in a DCI format triggering Type-3 codebook, which is used to indicate the priority for the PUCCH transmission conveying the triggered Type-3 codebook.***

***Proposal 9:*** ***For a given configured serving cell, HARQ-ACK corresponding to all configured HARQ processes should be multiplexed in a Type-3 codebook, irrespective of corresponding latest scheduled or configured priority for each HARQ process.***

***Proposal 10:*** ***For enhanced Type-3 codebook, support multiple codebook sizes.***

***Proposal 11:*** ***For enhanced Type-3 codebook, support dynamic indication or selection for the codebook size.***

***Proposal 12:*** ***Support the retransmission of cancelled HARQ-ACK by Type-2 codebook with clarification that PDSCH grouping is within each priority with maximum two PDSCH groups per priority.***

*Observation 1: Slot based PUCCH repetition for PUCCH formats 0 and 2 has been supported in M-TRP agenda.*

***Proposal 13:*** ***Support sub-slot based PUCCH repetition also for other UCI types, including SR and CSI.***

***Proposal 14:*** ***For PUCCH carrier switching Alt. 1, support including a new field in DL scheduling DCI to indicate the target PUCCH cell.***

***Proposal 15:*** ***For PUCCH carrier switching Alt. 1, SPS HARQ-ACK may be multiplexed with DG HARQ-ACK corresponding to non-fallback DCI format due to overlapping, then transmitted on the target PUCCH cell indicated for the DG HARQ-ACK.***

***Proposal 16: For PUCCH carrier switching Alt. 1, SPS HARQ-ACK, SR or CSI may be configured or indicated to be transmitted on same or different PUCCH cell(s).***

***Proposal 17:*** ***For PUCCH carrier switching Alt. 2C, the time domain pattern is configured commonly for a PUCCH cell group, and only an active PUCCH cell is expected at a given time.***

***Proposal 18:*** ***For PUCCH carrier switching Alt. 2C, support the followings:***

* ***A reference SCS/numerology for the time domain pattern is configured by RRC.***
* ***The reference SCS/numerology is smaller than or equal to a SCS/numerology*** $μ$ ***for any configured UL BWP for any PUCCH cell in the PUCCH cell group.***
* ***The granularity for the time domain pattern is a UL slot determined by the reference SCS/numerology.***

***Proposal 19:*** ***For PUCCH carrier switching, support configuring the K1 set individually for each PUCCH cell, for which the SCS/numerology of the PUCCH cell is applied.***

***Proposal 20:*** ***Support PUCCH carrier switching Alt. 2C at least for SR, as well as HARQ-ACK.***

### R1-2106636 HARQ-ACK Feedback Enhancements for URLLC/IIoT Nokia, Nokia Shanghai Bell

The discussions **in Sec. 2 on dropping of SPS HARQ-ACK feedback in TDD operation** can be summarized in the following related observations and proposals:

**Proposal 2.1: For the conditions for deferring SPS HARQ-ACK in the initial slot, in the case no dynamic PUCCH is scheduled on the initial slot, support Alt. 1: Defer if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using a PUCCH provided by *SPS-PUCCH-AN-List-r16* or *n1PUCCH-AN* is not valid.**

* **FFS: whether PUCCH resources in *multi-CSI-PUCCH-ResourceList* and *pucch-CSI-ResourceList* should also be considered as candidate resources for reporting the HARQ-ACK feedback in the initial slot or not.**

**Proposal 2.2: For SPS HARQ-ACK deferral, the target slot is determined as the earlier of a valid PUCCH of *sps-PUCCH-AN-List-r16* / *n1PUCCH-AN*, or a dynamically indicated PUCCH resource (from *PUCCH-ResourceSet*).**

**Proposal 2.3: For constructing the HARQ-ACK codebook in the target slot, the deferred SPS HARQ-ACK bits are simply amended to the initial HARQ-ACK bits in the target slot.**

**Proposal 2.4: SPS HARQ-ACK deferral is configured separately per SPS configuration.**

**Proposal 2.5: The maximum allowed deferral value *k1eff\_max* having value range up to 15 is configured per individual SPS configuration, i.e. as part of *SPS-Config*.**

The discussions **in Sec. 3 on PUCCH repetition enhancements** can be summarized in the following related observations and proposals:

***Observation 3.1: The working assumption on a configurable PUCCH repetition factor per PUCCH resource from the Coverage Enhancements WI seems to be directly applicable also for URLLC operation and no changes seem to be required. The interaction of the dynamic repetition indication and the Rel-15 RRC configured repetition numbers in ‘nrofSlots’ is better to be discussed as part of the Coverage Enhancements WI (in AI 8.8.2).***

**Proposal 3.1: For the Rel-15 RRC configured PUCCH repetition factor using ‘*nrofSlots*’ in *PUCCH-config*, the configured repetition factor is applicable for the same UCI types for sub-slot based PUCCH repetition as for slot-based PUCCH repetition, including HARQ-ACK, SR and CSI.**

**Proposal 3.2: The RRC configured PUCCH repetition factor using ‘*nrofSlots*’ in *PUCCH-config* for PUCCH formats 0 and 2 should be applicable for sub-slot and slot-based PUCCH configurations.**

**Proposal 3.3: RAN1 to discuss changes to the PUCCH repetition framework for URLLC/IIoT including:**

* **Change of dropping behavior for PUCCH repetition: Drop a PUCCH repetition overlapping with a high-priority DG PUSCH to prevent high-priority UL-SCH data dropping.**
* **Enable multiplexing of HARQ-ACK & SR (at least for PUCCH of priority index 1) to reduce SR latency.**

The discussions **in Sec. 4 on Type 1 HARQ ACK Codebook for sub-slot PUCCH and related enhancements** can be summarized in the following related observations and proposals:

**Proposal 4.1: For Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration, support TDRA pruning/grouping per DL slot after TDRA determination per UL sub-slot.**

The discussions **in Sec. 5 on retransmissions of dropped HARQ-ACK** can be summarized in the following related observations and proposals:

**Proposal 5.1: For Type 3 codebook enhancements for URLLC, RAN 1 to consider**

* **Limiting the enhanced Type 3 CB to RRC configured subsets of HARQ processes / IDs or serving cells**
* **Support dynamic indication of the RRC configured Type 3 CB subset from multiple enhanced Type 3 CB alternatives only by a triggering DCI that does not schedule PDSCH. For a triggering DCI also scheduling PDSCH, only a fixed single RRC configured enhanced Type 3 CB can be triggered.**
* **Including the support for Type 3 CB triggering using DCI format 1\_2.**
* **Triggering DCI including a PHY priority indication for the PUCCH carrying the Type-3 CB.**

**Proposal 5.2: Support one-shot HARQ-ACK codebook re-transmission on PUCCH with a dynamic indication of the timing of the HARQ-ACK CB (of a specific PUCCH occasion) to be re-transmitted. The re-transmission triggering DCI does not schedule PDSCH (allowing maintaining DCI size) and e.g. the HARQ ID field can be used to indicate the offset between the target PUCCH occasion and the PUCCH occasion of the HARQ-ACK CB to be re-transmitted.**



**Figure 5.1. Indication of the HARQ-ACK codebook to be retransmitted using the slot
for the PUCCH re-transmission as timing reference.**

**Proposal 5.3: For PUCCH carrying a triggered enhanced Type 3 HARQ-ACK codebook (of smaller size), only HARQ-ACK information of HARQ processes included in the enhanced Type 3 HARQ-ACK codebook are transmitted. Any ‘new, initial’ HARQ-ACK information for transmission in the same PUCCH slot that is not mapped to the enhanced Type 3 CB is not transmitted.**

**Proposal 5.4: For one-shot triggering of HARQ-ACK re-transmission on PUCCH, in case the dynamic Type 2 HARQ-ACK codebook is configured, the HARQ-ACK codebook on the indicated PUCCH is constructed by amending the Type 2 HARQ-ACK codebook to be re-transmitted to the Type 2 HARQ-ACK codebook of the indicated PUCCH (carrying new, initial HARQ-ACK information).**

**Proposal 5.5: For one-shot triggering of HARQ-ACK re-transmission on PUCCH, in case the semi-static Type 1 HARQ-ACK CB is configured, the HARQ-ACK codebook contains the Type 1 HARQ-ACK codebook to be re-transmitted. The UE does not expect to be triggered for new, initial HARQ-ACK transmission in the same PUCCH slot/sub-slot.**

The discussions **in Sec. 6 on dynamic PUCCH carrier switching** can be summarized in the following related observations and proposals:

**Proposal 6.1: The PUCCH carrier switching is limited to a maximum of three additional PUCCH cells (i.e. 4 PUCCH cells in total) for Rel-17.**

**Proposal 6.2: PUCCH carrier switching based on dynamic indication is in principle supported for PUCCH scheduled by DCI format 1\_1 or 1\_2 but not for PUCCH scheduled by the fallback DCI format 1\_0.**

**Proposal 6.3: Support an RRC configured list of target PUCCH cells in terms of serving cell indexes within *CellGroupConfig*, which is used for indexing of the target PUCCH cell for PUCCH carrier switching based on dynamic indication and/or semi-static time-domain pattern configuration.**

* **FFS: If the PCell/PSCell cell is included in the list (e.g. as the first entry) or if only the additional PUCCH cells are configured.**

**Proposal 6.4: Support the following flexible configurations for the DCI format usage and DCI bit field size:**

* **The dynamic indication of the target PUCCH cell using DCI format 1\_1 is RRC configured through the explicit new DCI field size configuration {i.e. 1 or 2 bit} for DCI format 1\_1 in *PhysicalCellGroupConfig*.**
* **The dynamic indication of the target PUCCH cell using DCI format 1\_2 is RRC configured through the explicit new DCI field size configuration {i.e. 1 or 2 bit} for DCI format 1\_2 in *PhysicalCellGroupConfig*.**

**Proposal 6.5: When DCI indicates PUCCH transmission in an Scell slot that is longer than Pcell slot, the following applies for HARQ-ACK multiplexing from Pcell:**

* **HARQ-ACK from a Pcell PUCCH overlapping with the indicated PUCCH on Scell is multiplexed on the SCell**
* **HARQ-ACK transmission configured or scheduled for more than one Pcell PUCCH slot overlapping with the indicated PUCCH on Scell is considered as an error case.**

**Proposal 6.6: When DCI indicates PUCCH transmission in an Scell slot that is shorter than the Pcell slot, the following applies for HARQ-ACK multiplexing:**

* **HARQ-ACK from overlapping Pcell PUCCH is multiplexed on Scell PUCCH**
* **Pcell PUCCH with HARQ-ACK overlapping with Scell PUCCHs in multiple Scell slots is considered as an error case.**

**Proposal 6.7: For PUCCH carrier switching based on dynamic indication, if the UE is configured with Type 1 HARQ-ACK codebook:**

* **The UE is not expected to be configured for a first (or second) PUCCH configuration with non-aligned PUCCH slots or sub-slots boundaries (i.e. start/end) across all configured PUCCH target cells.**
* **The UE is not expected to be configured with different k1 sets for a first (or second) PUCCH configuration across all configured PUCCH target cells.**

***Note: This is to limit the specification and implementation impact on the Type 1 HARQ-ACK codebook construction /pseudo code due to different k1 sets, SCS and slot/sub-slot configurations.***

***Observation 6.1: For PUCCH carrier switching based on dynamic indication, if the UE is configured with Type 2 HARQ-ACK codebook and the PCell and target PUCCH cell have the same SCS and slot- or same sub-slot based PUCCH configuration, the Rel-15/16 Type 2 HARQ-ACK codebook construction can be directly reused as the PUCCH slots or sub-slots are aligned across PCell and the target PUCCH cell.***

**Proposal 6.8: For PUCCH carrier switching based on dynamic indication, if the UE is configured with Type 2 HARQ-ACK codebook and PUCCH slots- or sub-slots of a PUCCH configuration are not aligned at the PCell and the target PUCCH cell, the following Type 2 HARQ-ACK construction is applied:**

* **The HARQ-ACK on PUCCH on PCell is only multiplexed on the target PUCCH cell, if the PUCCHs of PCell and target Scell are overlapping. In this case, the Type 2 CB DAI mechanism applies to the overall Type 2 CB to be transmitted on the target PUCCH cell.**
* **If the PUCCHs carrying HARQ-ACK on PCell and the target PUCCH cell are not overlapping, the HARQ-ACK is to be independently transmitted on PCell and the target PUCCH cell. The Type 2 CB DAI mechanism is independently applied for the Type 2 HARQ-ACK codebooks transmitted on PCell and the target PUCCH cell.**

**Proposal 6.9: PUCCH carrier switching, based on dynamic indication on DCI, should be limited to HARQ-ACK and SR only (i.e. PUCCH carrier switching for CSI is not to be supported).**

**Proposal 6.10: Support independent PUCCH TPC loops for the individual PUCCH cells within a cell group both for PUCCH carrier switching based on dynamic indication and semi-static configuration.**

**Proposal 6.11: For PUCCH TPC operation of PUCCH carrier switching based on dynamic indication and semi-static configuration, support the configuration of individual TPC command starting points within DCI format 2\_2 for each PUCCH candidate SCell in *PUCCH-TPC-CommandConfig*.**

**Proposal 6.12: For PUCCH carrier switching based on dynamic indication, the PUCCH TPC command in the DCI scheduling the PUCCH at the target PUCCH cell is applicable only for the (dynamically indicated) target PUCCH cell.**

**Proposal 6.13: For PUCCH carrier switching based on semi-static configuration, the PCell/PSCell SCS defines the reference numerology of the time domain pattern of applicable PUCCH cells. The PCell/PSCell is the reference cell for determining the PUCCH (sub-) slot to determine the PUCCH cell based on the configured time domain pattern of applicable PUCCH cells.**

**Proposal 6.14: The granularity of the time-domain pattern for PUCCH carrier switching is defined as an UL slot of the reference cell (i.e. PCell/PSCell).**

**Proposal 6.15: The gNB will need to guarantee by configuration of the time-domain pattern for PUCCH carrier switching, that the PUCCH carrier switching points are to be aligned with PUCCH slot/sub-slot boundaries of a PUCCH cell.**

**Proposal 6.16: The time-domain pattern is RRC configured per PUCCH cell group (i.e. within *CellGroupConfig*) for the UE and a pattern length of up to 10ms should be supported, i.e. a pattern length of up to *maxNrofSlots*.**

**Proposal 6.17:** **With semi-static PUCCH cell switching to longer Scell slot, gNB implementation takes care of that timelines are met for PUCCH transmission switching to Scell.**

**Proposal 6.18: With semi-static PUCCH cell switching to longer Scell slot, the UE does not expect to be indicated for HARQ-ACK codebooks in more than one of the PCell slots overlapping with a single Scell slot configured for PUCCH transmission.**

**Proposal 6.19: For PUCCH carrier switching based on semi-static configuration to an Scell with shorter slots, the PUCCH slot on the Scell is determined by combining PDSCH timing, indicated PCell k1 value, and indicated Scell k1\_relative value, where the k1\_relative value of the Scell indicates the Scell slot within the PCell slot.**

**Proposal 6.20: For PUCCH carrier switching based on semi-static configuration, the Type 1 HARQ-ACK codebook uses the k1 set(s) configured for the PCell / reference cell for the HARQ-ACK codebook construction.**

**Proposal 6.21: For PUCCH carrier switching based on semi-static configuration, the Rel-15/16 Type 2 HARQ-ACK codebook construction (based on the k1 interpretation on the PCell) can be directly reused.**

**Proposal 6.22: PUCCH carrier switching, based on semi-static configuration, should be limited to HARQ-ACK and SR only (i.e. PUCCH carrier switching for CSI is not to be supported).**

**Proposal 6.23: For PUCCH carrier switching based on semi-static configuration, the PUCCH TPC command in the DCI scheduling the PUCCH is applied for the determined PUCCH cell using the defined semi-static (i.e. time-domain pattern) PUCCH cell selection procedure.**

***Observation 6.2: Discussions on joint operation of dynamic and semi-static operation should be postponed after having more clarity on the operation of stand-alone PUCCH carrier switching based on (i) dynamic indication and (ii) semi-static configuration. A guiding principle for the potential joint operation of the two schemes could be that the dynamically indicated PUCCH Cell ‘overrides’ the determined PUCCH cell based on the time-domain PUCCH cell pattern.***

### R1-2106678 HARQ-ACK Enhancements for IIoT/URLLC Ericsson

In the previous sections we made the following observations:

* Observation 1 For the joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral, lower latency for SPS HARQ-ACK transmission can be achieved if PUCCH carrier switching of SPS HARQ-ACK is performed first.
* Observation 2 The semi-static configuration of PUCCH cell timing pattern containing ‘slot\_offset’ parameter can be used to obtain the SPS HARQ-ACK deferral behavior.
* Observation 3 The initial slot handling for SPS HARQ-ACK deferral essentially leads to a simple updated procedure on determining the new actual K1. This can be done separately prior to the existing multiplexing and PUCCH resource determination procedures.

Based on the discussion in the previous sections we propose the following:

**Proposal 1 Dynamic indication of a PUCCH carrier is done by a field in the DCI.**

**Proposal 2 Dynamic PUCCH carrier switching is applicable to any scheduled PUCCH carrying HARQ-ACK in response to dynamic PDSCH/ SPS PDSCH/ SPS release or triggered PUCCH carrying a Type-3 HARQ-ACK codebook.**

**Proposal 3 For semi-static PUCCH carrier switching, the PUCCH cell timing pattern contains PUCCH cell indices configured for each slot in the PCell or PUCCH-SCell of a PUCCH group.**

**Proposal 4 For semi-static PUCCH carrier switching, the PUCCH cell timing pattern consists of PUCCH cell index and slot offset values, (‘cell\_index’, ‘slot\_offset’) configured for each slot in the PCell or PUCCH-SCell of a PUCCH group.**

**Proposal 5 Semi-static PUCCH carrier switching is applicable to any PUCCH including PUCCH carrying SR, periodic/semi-persistent CSI, PUCCH carrying HARQ-ACK for SPS PDSCH/SPS release/dynamic PDSCH.**

**Proposal 6 PUCCH carrier switching mode ‘dynamic’, ‘semi-static’, or ‘dynamic and semi-static’ can be configured to a UE.**

**Proposal 7 A subset of applicable PUCCH cells for PUCCH carrier switching within a PUCCH group can be configured to a UE per PUCCH group.**

**Proposal 8 For dynamic indication of PUCCH carrier switching, the PUCCH carrier indicator field size is determined based on the largest set of applicable PUCCH cells among PUCCH groups subject to dynamic PUCCH carrier switching.**

**Proposal 9 If the UE is both indicated a PUCCH carrier indication by the DCI field and configured with PUCCH cell timing pattern, the UE follows the dynamic PUCCH carrier indication and ignores the semi-static PUCCH cell timing pattern.**

**Proposal 10 For joint operation of PUCCH carrier switching and UCI multiplexing, the UE first performs PUCCH carrier switching for relevant UCIs to determine the target PUCCH cell, and then the existing UCI multiplexing procedures are followed, if needed.**

**Proposal 11 The UE does not expect to be indicated with HARQ-ACK transmission in PUCCHs overlapping in different PUCCH carriers.**

**Proposal 12 If PUCCH resource with HARQ-ACK transmission with dynamic PUCCH carrier indication overlaps with semi-static configured PUCCH resources, the UE multiplexes UCIs and transmits on PUCCH on the carrier indicated by the dynamic indication.**

**• An exception can be considered when SPS HARQ-ACK is multiplexed with CSI, the PUCCH carrier to use follows the carrier intended for the CSI.**

**Proposal 13 For the joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral, PUCCH carrier switching of SPS HARQ-ACK is performed first, followed by SPS HARQ-ACK deferral on the target PUCCH cell, if needed.**

**Proposal 14 Support configuration of SPS HARQ-ACK deferral per SPS configuration (Option 2).**

**Proposal 15 Support Alt. 1A for the initial slot handling for SPS HARQ-ACK deferral.**

**Proposal 16 After the discussion on initial slot handling for SPS HARQ-ACK deferral is concluded, further discuss whether PUCCH resource determination enhancement for SPS HARQ-ACK in Alt. 2 is needed.**

**Proposal 17 Study potential update of Type-1 HARQ-ACK codebook procedure to support SPS HARQ-ACK deferral when k1eff is not included in the original set of configured K1 values. The update should not lead to an excessive increase of the HARQ-ACK codebook size.**

**Proposal 18 Support enhanced Type-3 HARQ-ACK codebook where only A/N of “activated CCs” are included in the codebook instead of all “configured CCs”.**

**Proposal 19 Introduce RRC configuration of a subset of HARQ processes of which the HARQ-ACK bits are included in the enhanced Type-3 HARQ-ACK codebook.**

**Proposal 20 For both Type-3 and enhanced Type-3 HARQ-ACK, support**

**- PHY priority indication can be included in the triggering DCI of the Type 3 and enhanced Type-3 HARQ-ACK codebook**

**- Both DCI formats 1\_1 and 1\_2 can be used for triggering the Type-3 and enhanced Type-3 HARQ-ACK codebook**

**- The priority indication is used only for selecting proper parameters for PUCCH transmission (i.e., proper PUCCH-config) and for the purpose of intra-UE prioritization**

**Proposal 21 When a HARQ-ACK codebook is dropped, the UE behavior with respect to the dropped HARQ-ACK is “as if the dropped HARQ-ACK codebook corresponds to DCI scheduling PDSCH with non-numerical K1 as in Rel-16”.**

**Proposal 22 Support a retransmission of the last dropped HARQ-ACK codebook by a DL assignment containing the timing and resource for the HARQ-ACK feedback.**

**Proposal 23 Support having a repetition factor for PUCCH repetition as part of the configuration of PUCCH resources and performing dynamic PUCCH repetition indication through the existing PRI field in the DCI (Confirming the working assumption in the CE WI).**

**Proposal 24 Dynamic PUCCH repetition can be applied to any UCI type (A/N, SR, CSI) and not limited only to HARQ-ACK.**

**Proposal 25 If a UE is configured with nrofSlots and is also provided with the dynamic repetition indication, the UE should follow the dynamic repetition indication and ignore the parameter nrofSlots.**

**Proposal 26 Support PUCCH repetition of PUCCH formats 0 and 2 also for slot-based PUCCH repetition for single TRP.**

**Proposal 27 Support Type-1 HARQ codebook for sub-slot HARQ-ACK by updating the pseudo code for determining a set of occasions for candidate PDSCH reception where the ratio 2^(μ\_DL-μ\_UL ) is changed to ⌊2^(μ\_DL-μ\_UL )/N⌋, where N is the number of sub-slots in an UL slot.**

### R1-2106697 Discussion on HARQ-ACK feedback enhancements for Rel-17 URLLC Spreadtrum Communications

***Proposal 1. For SPS HARQ-ACK deferral, a maximum deferring value can be configured by RRC signalling. If the RRC signalling does not exist, the maximum value of K1 set can be used as ae maximum deferring value.***

***Proposal 2. To handle Initial slot issue for SPS HARQ-ACK deferral, Alt. 2 is supported.***

***Proposal 3. For all the other configured PUCCH resources, a default rule can be used to choose one resource, e.g., the one with small resource index or the one with earliest starting symbol.***

***Proposal 4. The SPS HARQ-ACK deferral is configured per SPS configuration***

***Proposal 5. Support slot-based PUCCH repetition for PUCCH formats 0 and 2.***

***Proposal 6. Regarding how to how to indicate an enhanced Type 3 CB to the UE, using dynamic indication in the DCI is supported. The triggering DCI can also schedule PDSCH at the same time.***

***Proposal 7. NACK skipping should be supported, and it can be applied by both skipped and non-skipped SPS PDSCH.***

***Proposal 8. NACK skipping scheme can be configured by higher layer signalling for all configured SPSs.***

***Proposal 9. ACK skipping scheme can be considered for SPS HARQ payload size reduction of non-skipped SPS PDSCH.***

***Proposal 10. For Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration, support PDSCH TDRA grouping per sub-slot.***

### R1-2106734 Discussion on HARQ-ACK enhancements for eURLLC ZTE

***Observation 1:*** *Compared with Alt. 2, in order to support Alt. 1 (Type 3 CB), more issues need to be solved, which significantly increases the standardization work load.*

***Observation 2:*** *If multiple UL sub-slots correspond to a DL slot, it will potentially cause additional overhead for the type-1 HARQ-ACK codebook because the DL slot is used multiple times for construction of the type-1 HARQ-ACK codebook.*

***Observation 3:*** *Dividing SLIV group based on per slot can still work when UL sub-slot crossing 2 DL slots boundary.*

***Proposal 1:*** *The SPS HARQ-ACK deferral configured per SPS configuration should be supported.*

***Proposal 2:*** *Regarding the determination of valid symbols on SPS HARQ-ACK PUCCH deferring conditions:*

* *If an SPS HARQ-ACK PUCCH is determined to collide with the semi-statically configured* ***flexible*** *symbol in the slot, the SPS HARQ-ACK PUCCH should be transmitted.*

***Proposal 3:*** *Regarding SPS HARQ-ACK PUCCH deferring conditions:*

* *UE should determine whether the SPS HARQ-ACK PUCCH needs to be deferred before UCI multiplexing decision.*
* *UE determines the target slot from/within the initial slot/sub-slot.*

***Proposal 4:*** *Regarding the maximum value of k1def, it should be satisfied that the latest target UL slot/sub-slot corresponding to k1+k1def is the first UL slot/sub-slot after the initial slot/sub-slot.*

***Proposal 5:*** *For deferring HARQ-ACK until a next (e.g., first) available PUCCH, the PUCCH could be chosen from PUCCH resource sets for either SPS configuration or DG PDSCH starting from/within the initial slot.*

***Proposal 6:*** *For deferring HARQ-ACK until a next (e.g., first) available PUCCH, flexible symbols that from the start symbol of the original deferred PUCCH could be used for the available PUCCH for the deferred HARQ-ACK codebook.*

***Proposal 7:*** *For the next (e.g., first) available PUCCH for deferring HARQ-ACK, it needs to meet the following conditions in a slot:*

* *The size of the deferred HARQ-ACK codebook is within the UCI size range configured for the selected PUCCH.*
* *The number of the selected PUCCH symbols is not less than the number of original PUCCH symbols.*
* *The selected PUCCH has the earliest end symbol.*

***Proposal 8:*** *If the above conditions are not satisfied, the HARQ-ACK should be further deferred.*

***Proposal 9:*** *If the next available PUCCH for the deferred HARQ-ACK codebook for SPS PDSCH is determined in slot n and another PUCCH for the HARQ-ACK codebook for DG PDSCHs is also indicated in slot n, then the two HARQ-ACK codebooks should be multiplexed together in a same PUCCH determined by PRI in the last DCI.*

* *If the slot with SPS PDSCH is contained in the semi-static HARQ-ACK codebook window corresponding to the semi-static HARQ-ACK codebook for the DG PDSCHs, then UE constructs a new HARQ-ACK codebook containing the deferred HARQ-ACK and HARQ-ACKs of the DG PDSCHs according to the semi-static HARQ-ACK codebook mechanism, but the actual HARQ-ACK is always generated for the slot with SPS PDSCH.*
* *Otherwise, regardless of whether the UE is configured with a dynamic codebook or a semi-static codebook, the UE always concatenates the delayed HARQ-ACK codebook after the HARQ-ACK codebook for DG PUSCHs to generate a new HARQ-ACK codebook.*

***Proposal 10:*** *Regarding PUCCH repetition, especially sub-slot based PUCCH repetition:*

* *Regarding dynamic repetition indication, the method to be specified in Cov. Enh WI for slot-based PUCCH repetition can be directly applied to sub-slot PUCCH or changes are needed.*
* *‘nrofSlots’ is also applicable for sub-slot based PUCCH repetition.*
* *Both the dynamic indication and the number of sub-slots of PUCCH repetition configured by RRC should be supported, and the dynamic indication can override the RRC signaling.*
* *It is not necessary to consider slot-based PUCCH repetition for PUCCH formats 0 and 2.*

***Proposal 11:*** *RAN1 should consider the construction of the enhanced type 3 codebook based on the priority indication if the type 3 like codebook is supported for retransmission of the cancelled HARQ-ACK.*

***Proposal 12:*** *For the retransmission of the dropped HARQ-ACK codebook, Alt. 2 should be supported, i.e., DCI scheduling PUCCH to carry dropped HARQ-ACK codebook.*

* *In order to support one or more HARQ-ACK codebooks to be scheduled, the following detailed methods can be considered:*
	+ *Solution 1: Support a DCI triggering (by a DL assignment) of one HARQ-ACK codebook re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB in Rel-17.*
* *The identification bit is included in the DCI based on the configuration of the RRC signaling and indicates that the DCI is used to schedule the cancelled codebook.*
	+ *Solution 2: Support a new DCI format for scheduling one or more cancelled HARQ-ACK codebooks.*
* *The fields of size of one or more HARQ-ACK codebooks are included in the DCI.*
* *The order of the multiple size fields of one or more HARQ-ACK codebooks in the DCI is determined based on the order of the PUCCHs starting symbols corresponding to the cancelled HARQ-ACK codebooks.*
* *The CRC of the DCI is scrambled by a predefined RNTI.*
* *PUCCH resource indication (PRI), indicates a PUCCH resource from the carrier used to transmit PUCCH.*
* *PDCCH-to-HARQ\_feedback timing indicator, indicates the slot interval between the PDCCH where the DCI is located and the PUCCH used to transmit the scheduled HARQ-ACK codebook.*

***Proposal 13:*** *The standardization work for retransmission of the low-priority HARQ-ACK codebook should be considered first.*

* *The similar principle could be applied for high priority HARQ-ACK retransmission if it does not require a lot of extra standardization work compared to low priority HARQ-ACK retransmission.*

***Proposal 14:*** *The cancelled HARQ-ACK codebook should be triggered for transmission as early as possible after the conflict is determined, for example, the earliest trigger is started after the PDCCH corresponding to the high-priority PUCCH.*

***Proposal 15:*** *The unnecessary repetitive construction of the type-1 HARQ-ACK codebook due to the fact that one DL slot corresponds to multiple uplink sub-slots should be prohibited.*

***Proposal 16:*** *For the type-1 HARQ-ACK codebook, if one UL sub-slot overlaps with one or more DL slots, the existing mechanism is reused, for example, loop multiple DL slots within one UL slot.*

***Proposal 17****: Determine the type1 HARQ-ACK codebook based on sub-slot with grouping per slot level with the following procedure:*

1. *Determine the DL slot corresponding to the type1 HARQ-ACK codebook;*
2. *Within the determined DL slot, if the end symbol of a PDSCH TDRA does not overlap with the determined UL sub-slot (n-k1), then delete the PDSCH TDRA from the PDSCH TDRA of the determined DL slot;*
3. *The remaining PDSCH TDRA in the determined DL slot is divided into SLIV groups per slot level;*
4. *Generate HARQ-ACK information for each SLIV group.*

***Proposal 18:*** *For dynamic PUCCH carrier switching, dynamic indication in DCI should be supported.*

* *PRI is used to instruct PUCCH carrier switching from a new configured PUCCH resource set, which can include PUCCH resources of different UL CCs.*

***Proposal 19:*** *For the semi-static PUCCH carrier switching configuration operation:*

* *Support to configure multiple carriers for PUCCH carrier switching.*
* *Support the configuration of a reference carrier.*
* *Support periodic configuration of PUCCH carrier based on the slot of the reference carrier.*
* *k1 is interpreted based on the reference carrier.*
* *PRI is interpreted based on the target PUCCH carrier.*

### R1-2106801 Considerations on HARQ-ACK enhancements for URLLC Sony

**Observation 1: The gNB is aware if the UE missed a dynamically scheduled PUCCH that could have multiplexed SPS HARQ-ACKs due to their corresponding PUCCH being dropped and therefore the gNB knows that the UE has deferred these SPS HARQ-ACKs.**

**Observations 2: Considering multiple PUCCH resources in a slot regardless of whether they collide with the SPS PUCCH, for multiplexing of SPS HARQ-ACK would lead to high specification impacts to define rules to select one out of multiple PUCCH resources.**

**Observation 3: The Rel-16 HARQ-ACK CB for SPS is able to transmit HARQ-ACKs for multiple SPS’s that have the same HPN.**

**Observation 4: When a same-HPN collision occurs for two or more SPSs due to SPS HARQ-ACK deferral, the UE may have to drop the soft bits for one or more PDSCHs of these SPS from its HARQ buffer.**

**Observation 5: In a same-HPN collision involving an earlier SPS with deferred HARQ-ACK and a later SPS without a deferred HARQ-ACK, always dropping either the earlier or later SPS would have an impact on the HARQ retransmission gains.**

**Observation 6: Misdetection of DL Grant does not cause misalignment between gNB and UE on the number of retransmitted HARQ-ACK for a dynamic HARQ-ACK CB (Dyn-ReTx CB) that retransmits the HARQ-ACKs from a dropped Type 1 HARQ-ACK CB.**

**Observation 7: Misalignment between gNB and UE on the number of retransmitted HARQ-ACK of a dropped Type 2 HARQ-ACK CB using Dyn-ReTx CB may be caused by the UE miss detecting the last DL Grant, thereby missing the last DAI increment, associated with that Type 2 HARQ-ACK CB.**

**Observation 8: e-Type 3 HARQ-ACK CB would never provide effective overhead reduction because the CB size is semi-statically configured whilst which HARQ-ACKs get dropped happens dynamically.**

**Observation 9: The enhancements in e-Type 3 HARQ-ACK CB basically attempt to semi-statically “*predict*” which HARQ-ACK would be dropped and hence it can never achieve CB size as optimal as that of a dynamic HARQ-ACK CB, i.e. Dyn-ReTx CB, that retransmits only dropped HARQ-ACKs.**

**Observation 10: Dynamically indicate in the triggering DCI one of multiple configured e-Type 3 CBs of different HARQ-ACK subsets to better target which HARQ-ACKs that may be dropped dynamically have the following issues:**

* **Many e-Type 3 CBs are needed to adapt to the dynamically changing number of dropped HARQ-ACKs but this would lead to high DCI overhead or reduced functionality of the DL Grant triggering the e-Type 3 CB**
* **Using less bits in the DCI or RNTI as the indicator would limit the number of e-Type 3 CB that can be configured, hence making it less effective in overhead reduction**

**Observation 11: Configuring multiple e-Type 3 CBs and using a dynamic indicator in the triggering DCI to indicate which e-Type 3 CB to use is still not as effective in overhead reduction compared to using a dynamic HARQ-ACK CB, Dyn-ReTx CB, that retransmits only dropped HARQ-ACKs.**

**Observation 12: If the number of dropped HARQ-ACK is small, it is significantly more efficient to retransmit them using Dyn-ReTx CB than to use an e-Type 3 CB.**

**Observation 13: If the number of dropped HARQ-ACK is large, it is more robust to retransmit them using an e-Type 3 CB compared to Dyn-ReTx CB.**

**Observation 14: Sub-slot PUCCH repetitions would lead to intra-UE PUCCH collision where PUCCH repetitions in a sub-slot collide with another PUCCH in another sub-slot.**

**Observation 15: The 2 levels of L1 priority introduced in Rel-16 for UL intra-UE prioritization is not sufficient to handle inter sub-slot PUCCH repetitive collisions.**

**Observation 16: The 1st PUCCH repetition has the highest importance compared to subsequent repetitions of the same PUCCH.**

We therefore propose the following:

**Proposal 1: Use the condition in Alt-1 for deferment of SPS HARQ-ACK, i.e. deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by *SPS-PUCCH-AN-List-r16* or *n1PUCCH-AN* is not valid**

**Proposal 2: Reuse the Rel-16 SPS HARQ-ACK only CB to include deferred SPS HARQ-ACK.**

**Proposal 3: Reuse the Rel-16 mechanism to append deferred SPS HARQ-ACK to a dynamic HARQ-ACK CB.**

**Proposal 4: Do NOT agree the following Working Assumption:**

***Working assumption: To handle the collision for the same HARQ process due to deferred SPS HARQ-ACK the following behaviour is to be specified:***

* ***In case the UE receives PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.***

**Proposal 5: In a same-HPN collision involving two or more SPS due to SPS HARQ-ACK deferment, if the UE needs to drop PDSCH soft bits from one or more of these SPS’s, the UE will drop the SPS’s that has been successfully decoded.**

**Proposal 6: The dynamic HARQ-ACK CB (Dyn-ReTx CB) for HARQ-ACK retransmission is triggered using the “*One-shot HARQ-ACK request*” in DCI 1\_1. FFS whether to introduce “*One-shot HARQ-ACK request*” for DCI 1\_2.**

**Proposal 7: The DCI that triggers for the dynamic HARQ-ACK CB (Dyn-ReTx CB) to retransmit HARQ-ACK from a dropped Type 2 HARQ-ACK CB, will also indicate the DAI value of the last DL Grant associated with that dropped Type 2 HARQ-ACK CB.**

**Proposal 8: The UE is configured with the Dyn-ReTx CB and an e-Type 3 CB and when triggered by a DCI to retransmit HARQ-ACKs, the UE selects one of these CBs depending on the number of dropped HARQ-ACK:**

* **If the number of dropped HARQ-ACK ≤ *THARQ*, the UE selects Dyn-ReTx CB**
* **If the number of dropped HARQ-ACK > *THARQ*, the UE selects e-Type 3 CB**

**Proposal 9: If sub-slot PUCCH repetition is introduced, consider reducing the priority of a repetition according to the number of repetitions that have already been transmitted.**

### R1-2106879 On HARQ-ACK reporting enhancements Samsung

**Proposal 1: Support Alt. 2 “intra-slot deferral before inter-slot deferral” for SPS HARQ-ACK deferral.**

**Proposal 2: Support same principle for both initial slot and target slot for SPS HARQ-ACK deferral.**

**Proposal 3： Confirm the working assumption in RAN1#104e-bis with following update:**

**Updated Working assumption: To handle the collision for the same HARQ process due to deferred SPS HARQ-ACK the following behaviour is to be specified:**

* **In case the UE ~~receives~~ is configured to receive a PDSCH of a certain HARQ Process ID, the deferred SPS HARQ bit(s) for this HARQ Process ID are dropped.**

**Proposal 4: Support Type-3 CB triggering using DCI format 1\_2.**

* **The triggering using DCI format 1\_2 is RRC configured.**

**Proposal 5: RRC configures N report states (HPNs, cell IDs) for a Type-3 HARQ-ACK CB and a One-Shot HARQ-ACK request field of ceil(log2(N) bits in DCI format 1\_1/1\_2 indicates the report state.**

**Proposal 6: RRC configures N>1 report states (HPNs, cell IDs) for a Type-3 HARQ-ACK CB and a One-Shot HARQ-ACK request field of 1 bit in DCI format 1\_1/1\_2 and, when the One-Shot HARQ-ACK request field value is 1, there is no scheduled PDSCH and a redundant field indicates the report state.**

**Proposal 7: RRC configures a One-Shot HARQ-ACK request field of N bits in DCI format 1\_1/1\_2 that triggers from a UE a HARQ-ACK report that the UE was scheduled to provide in one of the previous 2N-1 UL slots or one of the previous N UL slots in case of a bitmap.**

**Proposal 8: RRC configures a One-Shot HARQ-ACK request field of 1 bit in DCI format 1\_1/1\_2 and, when the One-Shot HARQ-ACK request field value is 1 and the Rel-16 conditions for no scheduled PDSCH are satisfied, redundant field(s) provide a bitmap that indicates previous UL slots and a UE is triggered to provide HARQ-ACK reports that the UE was scheduled to provide in the indicated previous UL slots.**

**Proposal 9: Support skipping of a PUCCH transmission with NACK-only HARQ-ACK information.**

**Proposal 10: Support all UCI types for sub-slot based PUCCH repetition.**

**Proposal 11: Type-1 codebook for sub-slot based PUCCH supports PDSCH TDRA grouping per DL slot as in Rel-15/16.**

**Proposal 12: The maximum number of PUCCH cells is 2.**

**Proposal 13: The unit of the time pattern is the slot of the cell with the smaller SCS.**

**Proposal 14: The time unit of the PDSCH-to-HARQ\_feedback timing field for RRC-based PUCCH cell switching is based on the smaller SCS of the PUCCH cells. When a UE is indicated to transmit PUCCH on the cell with larger SCS, the UE transmits the PUCCH in the first slot that overlaps with the indicated slot on the cell with smaller SCS.**

**Proposal 15: When a slot of a first cell overlaps with one or more slots of a second cell, a UE does not expect to transmit PUCCH in both the slot of the first cell and in any of the one or more slots of the second cell.**

**Proposal 16: When a UE is indicated a slot by a DCI format that overlaps with a slot indicated by a PUCCH cell timing pattern, the UE determines the cell for a PUCCH transmission from the indication by the DCI format.**

**Proposal 17: Conclude whether or not a UE can expect to transmit PUCCH (with HARQ-ACK associated with DCI formats) on a SCell/P(S)Cell when the UE can transmit PUCCH with HARQ-ACK for SPS PDSCHs or SR/CSI on P(S)Cell/SCell.**

**Proposal 18: A field of 1 bit in DCI formats 1\_1/1\_2 indicates the cell of an associated PUCCH transmission. If PUCCH cell switching is to be supported using DCI format 1\_0, 1 bit from the HPN or RV field indicates the cell of an associated PUCCH transmission.**

**Proposal 19: Support PUCCH cell switching for all UCI types.**

**Proposal 20: A UE is separately provided a *pucch-Config* for each BWP of the PUCCH SCell.**

**Proposal 21: Maintain PUSCH reception robustness due to multiplexing 1-2 HARQ-ACK bits from dynamic scheduling also when multiple HARQ-ACK bits from SPS PDSCH receptions are multiplexed in the PUSCH.**

**Proposal 22: Remove duplicated HARQ-ACK information from the Type-1 HARQ-ACK codebook for intra slot PDSCH repetition.**

**Proposal 23: The HARQ-ACK timing indicator counts only slots with PUCCH resources.**

The following are observations in this contribution.

***Observation 1****: If a Type-3 CB is associated with a priority, there is no need to differentiate LP HARQ-ACK and HP HARQ-ACK, particularly for an “enhanced” Type-3 CB of Rel-17.*

***Observation 2****: RRC configuration suffices for determining a triggered “enhanced” Type-3 HARQ-ACK codebook size.*

***Observation 3****: Consideration of only activated cells or of only cells with non-dormant active DL BWPs, instead of configured cells, is a general issue for constructing Type-1/Type-3 HARQ-ACK codebooks, and for partitioning PDCCH candidates/CCEs among scheduling cells, and should not be considered in isolation for a Type-3 HARQ-ACK codebook.*

***Observation 4****: RRC configured PUCCH cell timing pattern is sufficient to determine the cell of PUCCH transmission, regardless of SCS, and to support SPS HARQ-ACK deferral.*

***Observation 5****: A UE should not expect to be indicated by separate DCI formats to transmit PUCCHs in overlapping slots of different cells.*

### R1-2106962 UE feedback enhancements for HARQ-ACK CATT

***Proposal 1: Whether SPS HARQ-ACK should be deferred*** ***is determined based on the PUCCH resource for SPS HARQ-ACK only regardless of whether there are HARQ-ACK(s)*** ***corresponding to dynamic PDSCH and/or SPS PDSCH release to be transmitted in the same slot/sub-slot.***

***Proposal 2: If an initial PUCCH resource for SPS HARQ-ACK only in a slot indicated by K1 is not available, the SPS HARQ-ACK should be deferred to a slot in which the initial PUCCH resource is available.***

***Proposal 3: For multiplexing of deferred HARQ-ACK and initial HARQ-ACK, the HARQ-ACKs for deferred SPS HARQ-ACK are appended to the initial HARQ-ACKs.***

* ***FFS for optimizations for Type-1 HARQ-ACK codebook.***

***Proposal 4: PUCCH resource for multiplexing the deferred SPS HARQ-ACK and initial SPS HARQ-ACK (which is not deferred) or dynamic HARQ-ACK is determined based on the total number of HARQ-ACK bits following Rel-16 rules.***

***Proposal 5: The target slot/sub-slot for SPS HARQ-ACK deferral is not changed after determination.***

***Proposal 6: Confirm the working assumption that at least one enhanced Type 3 HARQ-ACK CB with smaller size (compared to Rel-16) in Rel-17 is supported.***

***Proposal 7: Enhanced Type-3 codebook which includes HARQ-ACKs for HARQ processes of SPS PDSCHs only is supported.***

***Proposal 8: Type-3 codebook and enhanced Type-3 codebook are distinguished by RRC configuration only.***

***Proposal 9: The PHY priority indicated in triggering DCI is used to determine the priority of the PUCCH resource used for the enhance Type-3 codebook and the enhanced Type-3 codebook is constructed independently from the PHY priority indication.***

***Proposal 10: An additional DCI field can be added in DCI format 1\_2 to trigger (enhanced) Type-3 codebook.***

***Proposal 11: Confirm the working assumption that one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB in Rel-17 is supported.***

***Proposal 12: For one-shot triggering of dropped HARQ-ACK, the offset between the slot for triggering DCI and slot with dropped HARQ-ACK can be indicated by the triggering DCI to identify which ‘dropped HARQ-ACK’ should be re-transmitted.***

***Proposal 13: For one-shot triggering of dropped HARQ-ACK, the retransmitted HARQ-ACK bits can be appended to the initial HARQ-ACK codebook.***

***Proposal 14: For PUCCH carrier switching based on dynamic indication in DCI, SPS HARQ-ACK can be multiplexed with dynamic HARQ-ACK in the same slot if dynamic HARQ-ACK is indicated to be transmitted on the switched cell and the other configured PUCCH resources can be dropped if they are in the same slot with the switched dynamic HARQ-ACK;***

* ***For the case of different numerologies, the slot based the smallest SCS can be used as the reference slot.***

***Proposal 15: For PUCCH carrier switching based on semi-static RRC configuration, the granularity of switching pattern should be determined based on the slot of the PUCCH cell with smallest SCS configuration.***

***Proposal 16: For PUCCH carrier switching based on semi-static RRC configuration,***

* ***the PUCCH resource for dynamic HARQ-ACK on target SCell is determined by PRI indication and PUCCH resource configuration on SCell;***
* ***semi-static PUCCH resource on target SCell is determined by dedicated PUCCH resource configured for the target SCell.***

***Proposal 17: For the case of different SCS configurations between PUCCH carriers,***

* ***In case the PCell has larger SCS, multiplexing HARQ-ACKs in different slots on PCell to a PUCCH on SCell should be avoided by gNB;***
* ***In case the PCell has smaller SCS, PUCCH resource should be mapped to the first slot/sub-slot on the target SCell overlapping with the slot on PCell for PUCCH transmission.***

***Proposal 18: For joint operation of dynamic and semi-static PUCCH carrier switching, it is not expected that the target PUCCH cell determined based on dynamic indication in DCI is different from the PUCCH cell determined by switching pattern configured for semi-static PUCCH carrier switching scheme.***

***Proposal 19: If joint operation of PUCCH carrier switching and SPS HARQ-ACK deferral is supported, it is preferred to perform PUCCH carrier switching first.***

***Proposal 20: The maximum number of cells for PUCCH carrier switching is two.***

***Proposal 21: Configuring the PUCCH repetition factor per PUCCH resource can be applied for both slot and sub-slot based PUCCH.***

***Proposal 22: Configuring the PUCCH repetition factor per PUCCH resource can be applied for all UCI types.***

***Proposal 23: For sub-slot based Type-1 HARQ-ACK codebook, the PDSCH TDRA grouping should be performed per DL slot.***

### R1-2107025 Discussion on UE feedback enhancements for HARQ-ACK Panasonic

**Proposal 1: The SPS HARQ-ACK deferral should be configured per SPS configuration.**

**Proposal 2: On the condition of SPS HARQ-ACK deferral, following Alt.1 should be supported. Our second preference is the following modification of Alt.1A.**

* **Alt.1: Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid.**
	+ **If SPS HARQ-ACK is multiplexed with any other UCI / dynamic PUCCH resource, then it cannot be deferred.**
* **Alt.1A: Deferral only, if the PUCCH resource configured by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN for the HARQ-ACK transmission assuming SPS HARQ-ACK only is not valid in the initial slot/sub-slot.**
	+ **If SPS HARQ-ACK PUCCH resource is overlapping, it will be deferred even though it could still be multiplexed e.g., due to PRI overriding.**

**Proposal 3: Even if all SPS HARQ-ACK bits are not able to be sent in the PUCCH, the SPS HARQ-ACK bits should be transmitted as much as possible utilizing full capability of selected PUCCH format instead of dropping SPS HARQ-ACK bits.**

**Proposal 4: The codebook size of triggered Type-3 HARQ-ACK codebook is determined by RRC configuration and/or activation.**

**Proposal 5: DCI format 1-2 supports triggering Rel.16 Type 3 HARQ-ACK codebook and Rel.17 enhanced Type 3 codebook with smaller size**

**Proposal 6: PHY priority is supported for Rel.16 Type 3 HARQ-ACK codebook and Rel.17 enhanced Type 3 codebook with smaller size. The indicated PHY priority in the triggering DCI defines the PHY priority of the PUCCH carrying the Type 3 HARQ-ACK codebook.**

**Proposal 7: For one-shot triggering of HARQ-ACK retransmission on a PUCCH, the HARQ-ACK codebook to be retransmitted is explicitly indicated in the triggering DCI.**

**Proposal 8: For dynamic repetition factor indication for sub-slot-based PUCCH, the method to be specified in CovEnh WI for slot-based PUCCH repetition is directly applied to sub-slot PUCCH.**

**Proposal 9: For sub-slot-based PUCCH, both semi-static based PUCCH repetition factor “nrofSlots’ and dynamic based PUCCH repetition factor ‘nrofSlots-r17’ should be supported if sub-slot-based PUCCH repetition and dynamic repetition indication are separate UE features.**

**Proposal 10: Dynamic and semi-static PUCCH carrier switching should be configured and enabled for dynamic scheduling and SPS separately.**

**Proposal 11: For dynamic PUCCH carrier switching, the target carrier can be derived from the PRI field. To enlarge PRI field should be considered.**

**Proposal 12: Configure additional timing offset values for PDSCH to HARQ-ACK for the PUCCH carries.**

**Proposal 13: To enable dynamic and semi-static PUCCH carrier switching schemes simultaneously, one of the alternatives should be considered**

* **a dedicated indication can be configured in DCI for switching between two schemes,**
* **the semi-static carrier switching is applied when the PUCCH transmission is not possible over the dynamic indicated carrier.**

**Proposal 14: When semi-static carrier switching is enabled along with the SPS HARQ-ACK deferral, the UE should first apply HARQ-ACK deferral according to the PCell and then identifies the PUCCH carrier accordingly.**

### R1-2107133 Discussion on UE feedback enhancements for HARQ-ACK China Telecom

**Proposal 1: Whether the SPS HARQ-ACK is subject to deferral is jointly configured by RRC per PUCCH cell group.**

**Proposal 2: Inter-slot/sub-slot deferral happens when there is no available PUCCH resource with valid symbols in the initial slot/sub-slot.**

**Proposal 3: When SPS HARQ-ACK is deferred to available PUCCH resource, load balance should be considered when determining the available resource.**

* **If the payload/ code rate on a PUCCH resource is larger than a payload/ code rate threshold, the PUCCH resource is not available.**

**Proposal 4: For PUCCH carrier switching based on RRC configured PUCCH cell timing pattern, RRC configures a time unit and a period with the smallest SCS of the candidate PUCCH carriers as the reference SCS. The carrier configured for the time unit containing the slot/sub-slot determined by K1 is used for PUCCH transmission. The reference SCS for K1 is the SCS of Pcell/PScell/PUCCH-SCell.**

### R1-2107156 UE feedback enhancements for HARQ-ACK NEC

**Proposal 1:**

* *Support Type-1 HARQ-ACK codebook construction for sub-slot PUCCH configuration based on PDSCH TDRA grouping per DL sub-slot.*

**Proposal 2:**

* *Further study the HARQ-ACK location determination for SPS release in the Type-1 HARQ-ACK codebook based on sub-slot PUCCH configuration.*

**Proposal 3:**

* *HARQ-ACK bits will only be present in the semi-static type-1 codebook if the corresponding sub-slot has at least one PDCCH transmission or SPS PDSCH reception.*

**Proposal 4:**

* *Support deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid.*

**Proposal 5:**

* *Support multiplexing the deferred HARQ-ACK for SPS PDSCH and HARQ-ACK for dynamically scheduled PDSCH(s) on a Type-1 HARQ-ACK codebook.*
	+ *Append the deferred HARQ-ACK bits for SPS PDSCH(s) after the HARQ-ACK codebook for dynamically scheduled PDSCH(s) If the value of k1eff for SPS HARQ-ACK is not in the configured K1 set.*

**Proposal 6:**

* *Confirm the working assumption to support retransmission of cancelled HARQ-ACK in Rel-17.*

**Proposal 7:**

* *Support dynamic triggering of an enhanced Type-3 CB of HARQ-ACK re-transmission for SPS PDSCH only.*
	+ *Following alternatives can be considered to reduce the HARQ-ACK codebook size:*
		- *Alt.1: The requested HARQ-ACK codebook contains the number of all DL HARQ processes for all the configured/activated SPS configuration(s) in the configured CC(s).*
		- *Alt.2: The requested HARQ-ACK codebook contains only the number of DL HARQ processes for the indicated SPS configuration(s) in the configured CC(s).*
		- *Alt.3: The requested HARQ-ACK codebook contains a set of DL HARQ processes for the configured/activated SPS configuration(s) in the configured CC(s).*

**Proposal 8:**

* *For one-shot triggering of HARQ-ACK retransmission on a PUCCH resource in Rel-17, support multiplexing of retransmitted HARQ-ACK and initial HARQ-ACK.*
	+ *Further study how to multiplex retransmitted HARQ-ACK and initial HARQ-ACK on Type-1 HARQ-ACK codebook and Type-2 HARQ-ACK codebook.*

**Proposal 9:**

* *Supporting joint operation of dynamic and semi-static carrier switching for a UE is slightly preferred.*

**Proposal 10:**

* *Support the numerology associated with the largest SCS of the involved candidate cells as the reference numerology for the definition of the time domain pattern of semi-static PUCCH carrier switching.*
* *Support a UL slot as the time granularity for the time domain pattern of semi-static PUCCH carrier switching.*

 **Proposal 11:**

* *For semi-static PUCCH carrier switching, further study how to determine the slots/sub-slots and target cell for PUCCH repetition transmissions.*

**Proposal 12:**

* *For dynamic PUCCH carrier switching, in case PUCCH on a CC for SPS HARQ-ACK is overlapped with the PUCCH on another CC for dynamic scheduled HARQ-ACK in time domain, support multiplexing SPS HARQ-ACK and DG HARQ-ACK on the PUCCH resource for DG HARQ-ACK.*
	+ *FFS the Type-1 HARQ-ACK codebook construction for multiplexing SPS HARQ-ACK and DG HARQ-ACK.*

**Proposal 13:**

* *Support joint operation of dynamic PUCCH carrier switching and SPS HARQ-ACK deferral.*
	+ *When the joint operation is configured, PUCCH carrier switching for SPS HARQ-ACK has priority over SPS HARQ-ACK deferral.*

**Proposal 14:**

* *Further study the PUCCH power control for PUCCH carrier switching.*

**Proposal 15:**

* *Further study how to configure PUCCH resource for a set of candidate cells for PUCCH carrier switching.*

### R1-2107180 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility

**Proposal 1: A UE defers HARQ-ACK, if a corresponding HARQ-ACK codebook consists of only HARQ-ACK information for SPS PDSCH(s) without a corresponding PDCCH(s).**

**Observation 1: For Type-1 (i.e. semi-static) HARQ-ACK codebook, the Rel-15/16 codebook construction method is not directly applicable to deferred HARQ-ACK (i.e. K1 value for PDSCH-to-HARQ feedback timing needs to be redefined).**

**Observation 2: For Type-2 (i.e. dynamic) HARQ-ACK codebook, deferred SPS PDSCH HARQ-ACK bits may need to be re-ordered, if additional SPS PDSCH HARQ-ACK bits are multiplexed in a newly determined PUCCH resource.**

**Proposal 2: Support deferred HARQ-ACK transmission with concatenation of a delayed HARQ-ACK codebook and a current scheduled HARQ-ACK codebook to construct an aggregated HARQ-ACK codebook.**

**Proposal 3: DCI triggering HARQ-ACK retransmission includes** **information of cancelled HARQ-ACK transmission occasions for retransmission, e.g. a number of cancelled HARQ-ACK codebooks to be included for retransmission and timing information of the cancelled HARQ-ACK transmission occasions.**

**Proposal 4: Support implicit triggering of HARQ-ACK retransmission based on indication of two HARQ-ACK transmission occasions in DCI.**

**Proposal 5: Support autonomous one-shot HARQ-ACK re-transmission for all or a subset of HARQ processes in a CG-PUSCH resource, where the CG-PUSCH is available in an earlier slot/sub-slot than a slot/sub-slot where the earliest available PUCCH resource for HARQ-ACK is.**

### R1-2107272 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO

***Proposal 1: SPS HARQ-ACK deferral should be configured by RRC per SPS configuration.***

***Proposal 2: The maximum value of the total PDSCH to HARQ-ACK delay/offset, i.e. k1+k1def, of one SPS configuration is same as the maximum value of K1 set corresponding to the DCI format used to activate the SPS configuration.***

***Proposal 3: When both SPS HARQ-ACK deferral and PUCCH repetition are configured, for a SPS PDSCH reception ending in slot/subslot n, if the first PUCCH occasion is no later than slot/subslot n+k1+k1def,***

* ***if the last PUCCH occasion is no later than slot/subslot n+k1+k1def, a UE transmits the PUCCH as Rel-15/16;***
* ***otherwise, the UE transmits the PUCCH repetition(s) no later than slot/subslot n+k1+k1def and cancels the PUCCH repetition(s) after slot/subslot n+k1+k1def.***

***Proposal 4: Deferral should be before multiplexing decision.***

***Proposal 5: To determine the target slot/subslot for deferring SPS HARQ-ACK, starting from the initial slot/subslot,***

* ***Deferral only, if the SPS HARQ-ACK in one slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid.***

***Proposal 6:*** ***SPS PUCCH resources carrying N bits can be used as the candidates to check the validity of a SPS PUCCH resource for M-bit SPS HARQ-ACK associated to a slot, where N≥M.***

***Proposal 7: To check the validity of a slot for deferral of SPS HARQ-ACK,***

* ***If a PUCCH resource A, determined based on all SPS HARQ-ACKs associated to the slot, is not valid, and a PUCCH resource B, determined based on urgent SPS HARQ-ACKs (i.e. HARQ-ACKs for the SPS PDSCH with the maximum value of k1+ k1def and/or*** ***SPS PDSCH not configured with SPS deferral), is valid, the UE transmits the urgent SPS HARQ-ACKs in the slot;***
* ***Otherwise, check the validity of next slot for deferral.***

***Proposal 8: At least one subset of serving cells is configured by RRC, and DCI indicates one subset for enhanced Type 3 HARQ-ACK feedback.***

***Proposal 9: Self-carrier triggering for enhanced Type 3 HARQ-ACK CB can be supported as a special case, i.e. a DCI used to schedule cell X can only trigger an enhanced Type 3 HARQ-ACK CB contains the HARQ-ACKs for the HARQ processes on cell X.***

***Proposal 10: If multiple enhanced Type 3 HARQ-ACK CBs constructed based on different subsets are triggered in one slot/subslot, an enhanced Type 3 HARQ-ACK CB containing the HARQ-ACKs constructed based on the union of multiple subsets should be transmitted in the slot/subslot.***

***Proposal 11:*** ***Implicit indication of a retransmitted HARQ-ACK CB for one-shot*** ***triggering of HARQ-ACK retransmission on a PUCCH resource can be considered.***

***Proposal 12: To determine a set of occasions for candidate PDSCH receptions for subslot-based Type-1 HARQ-ACK CB:***

* ***Step 1: Determine candidate DL subslots corresponding to one UL subslot based on the K1 set.***
* ***Step 2: If the last symbol of a PDSCH TDRA row r is not in the candidate DL subslots, row r is removed from the candidates of TDRA rows.***
* ***Step 3: Determine occasions for candidate PDSCH receptions based on the remaining PDSCH TDRA rows.***

***Proposal 13: To support PUCCH carrier switching***

* ***At most 2 PUCCH cells for PUCCH carrier switching can be configured to one UE.***
* ***Dynamic carrier switching or semi-static carrier switching can be configured,***
	+ - ***Additional*** ***enhancement on joint operation, including joint operation between dynamic carrier switching and semi-static carrier switching, and joint operation between carrier switching and SPS HARQ-ACK deferral is not supported.***

### R1-2107296 Discussion on UE feedback enhancements for HARQ-ACK FGI, Asia Pacific Telecom

Proposal 1 k1eff,max is configured per SPS configuration.

Proposal 2 The size of SPS HARQ-ACK codebook in a slot should be determined based on the number of non-deferred SPS HARQ-ACK bits and the number of SPS HARQ-ACK bits that may be deferred to the slot.

Proposal 3 Support triggering a Type-3 HARQ-ACK codebook by DCI format 1\_1 and DCI format 1\_2.

Proposal 4 When the priority indicator in a DCI triggering a Type-3 HARQ-ACK codebook indicates a PUCCH of low priority or a PUCCH of high priority, the PUCCH resource for the Type-3 HARQ-ACK codebook should be selected based on the payload size of the Type-3 HARQ-ACK codebook and the PRI in the triggering DCI, from the PUCCH resources configured in the first PUCCH-Config or in the second PUCCH-Config, respectively..

Proposal 5 A list of pdsch-HARQ-ACK-OneShotFeedbackCBG-r16 is used to indicate the presence of CBG HARQ-ACK bits in the Type-3 HARQ-ACK codebooks triggered by DCI formats indicating low priority and high priority.

Proposal 6 A list of pdsch-HARQ-ACK-OneShotFeedbackNDI-r16 is used to indicate the presence of NDI bits in the Type-3 HARQ-ACK codebooks triggered by DCI formats indicating low priority and high priority.

Proposal 7 For RRC configured PUCCH cell timing pattern, the information included in the pattern should be specified.

Proposal 8 The PUCCH cell timing pattern configuration can contain sets of bits with each set of bits indicating the target cell for each slot within a period. The PUCCH cell timing pattern configuration can contain periodicity to determine how may slots the PUCCH cell timing pattern are indicated. The PUCCH cell timing pattern configuration can contain a duration to indicate the time duration within it the PUCCH cell timing pattern is repeatedly applied.

Proposal 9 Mutiple PUCCH cell timing pattern can be configured, and each PUCCH cell timing pattern can have an associated index which can be indicated dynamically for faster switching between different patterns.

Proposal 10 Either a configurable maximum number of PUCCH cells or not setting a limit on maximum number of PUCCH cells is preferred.

Proposal 11 Applying semi-static carrier switching to all slots as basis and further changing the indicated PUCCH carrier for a slot by DCI can be considered.

### R1-2107336 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated

***Observation 1: Deferring SPS PUCCH A/N to “1st available PUCCH resource” does not always guarantee that the 1st available PUCCH resource is indeed available. This is a valid argument in cases of multiple SPS HARQ deferrals; presence of other HARQ bits, either for DG traffic or for non-deferred HARQ bits. In order to avoid collisions with other PUCCHs or PUSCHs for other UEs, which might lead to HARQ bits dropping or to further deferral, other mechanism controlled by the network are needed.***

***Observation 2: In a well planned radio access network, SPS PUCCH HARQ deferrals should not happen; if they happen, this is going to be an unusual case and several UEs in the cell will be affected.***

***Observation 3: The scenario of cancelling PUSCH and piggybacked HARQ bits is a strong case in URLLC scenarios.***

***Observation 4: The scenario of the UE internally dropping/cancelling LP PUCCH due to own HP PUCCH although theoretically possible should not be the driver for the work for cancelled/dropped HARQ bits in URLLC.***

***Observation 5: The work in specifying solutions for the scenario of SPS PUCCH HARQ bits colliding with DL symbols was initiated without any direct reference to any URLLC/IIOT scenario among the ones of TS 22.104.***

In summary, we make the following proposals for HARQ-ACK feedback enhancement for Rel-17 IOT and URLLC.

***Proposal 1: SPS HARQ-ACK deferral to the 1st available PUCCH should be configured per SPS configuration. If a PUCCH transmission consists of HARQ-ACK for at least one SPS configuration with deferral, the PUCCH transmission is deferred to the 1st available PUCCH.***

***Proposal 2: Maximum deferral value is configured at RRC per SPS configuration. UE will not retransmit the collided A/N bit after k1\_def\_max slots from the end of the slot where SPS A/N PUCCH collision happens.***

* ***In case of a PUCCH transmission containing HARQ-ACK bits from different SPS configurations with different maximum deferral values, the maximum of those maximum deferral values is applied.***

***Proposal 3: If a PUCCH for SPS HARQ ACK info is dropped due to overlapping with DL or flexible symbol indicated by dynamic SFI, the “SPS HARQ ACK deferral to 1st available PUCCH” will not be applied to this case, i.e. no further deferral for this dropped PUCCH.***

***Proposal 4: Multiplexing of DG UCI with SPS PUCCH HARQ-ACK in a PUCCH PRI which then collides with semi-static DL symbols, SSB, or CORESET#0 is handled as error case by the UE.***

***Proposal 5: When the colliding PUCCH contains both SPS HARQ and CSI, only SPS HARQ-ACK is deferred to the 1st available PUCCH and CSI is dropped.***

***Proposal 6: Upon “SPS PUCCH HARQ deferral to 1st available PUCCH resource” consider intra-slot deferral before inter-slot deferral.***

***Proposal 7: If the selected PUCCH carrying deferred A/N bits overlaps with DL transmission-scheduled by DCI in the target slot or DL/flexible symbol indicated by DCI format 2\_0, UE drops the deferred A/N bits without their further deferral.***

***Proposal 8: Support that A/N bits from multiple collided PUCCHs CAN be deferred to the same new PUCCH.***

***The new CB in the new PUCCH is the concatenation of individual CBs originally from those collided PUCCHs based on their order in time.***

***Proposal 9: At least when there is no existing non-deferred UCI bit in a candidate target slot, and if that slot cannot accommodate the PUCCH selected for all collided A/N bits.***

* ***UE does not transmit any collided A/N bit in that slot. UE will continue to check next candidate slot for transmitting all collided A/N bits.***

***Proposal 10: In presence of existing non-deferred A/N bit(s) in the target slot, support that both collided and existing A/N bit(s) CAN be transmitted in the same PUCCH.***

* ***The new CB in the PUCCH is the concatenation of the CB for existing A/N bit(s) and the individual CB(s) originally from collided PUCCH(s).***

***Proposal 11: In presence of existing non-deferred A/N bit(s) for SPS in a candidate target slot, if that slot cannot accommodate the PUCCH selected to carry both existing and collided A/N bits.***

* ***UE does not transmit any A/N bit in that slot. UE will treat all existing and collided A/N bits as collided A/N bits and continue to check next candidate slot for transmitting all collided A/N bits that are not expired.***

***Proposal 12: On whether to allow partial deferral***

* ***Not support deferral of only part of A/N bits in collided PUCCH.***

***Proposal 13: If deferred SPS A/N and DG A/N are in the same target slot, support multiplex both SPS and DG A/N on the same PUCCH indicated by PRI as in R15/16.***

***Proposal 14:******For SPS HARQ collision with DL symbols, RAN 1 to study whether and how to support either:***

* ***“SPS PUCCH HARQ deferral to 1st available PUCCH resource”, or***
* ***“PUCCH Carrier Switch” (in case of more than 1 PUCCH CCs), or***
* ***“1-shot Enhanced Type 3 CB HARQ”, or***
* ***Joint configuration of any of the above, whenever applicable.***

***Proposal 15:*** ***Upon joint configuration of any combination of “SPS PUCCH HARQ deferral to 1st available PUCCH resource”, “PUCCH carrier switching” and “1-shot Enhanced Type 3 CB HARQ”, execution of “SPS PUCCH HARQ deferral to 1st available PUCCH resource” starts immediately after the SPS PUCCH HARQ deferral triggering and it stops:***

* ***When appropriate PUCCH resource for the transmission of deferred HARQ is found, or***
* ***When a request for “1-shot Enhanced Type 3 CB” is received, or***
* ***When a “PUCCH-carrier switch command” is received in DCI (in case of more than 1 PUCCH CCs)***
* ***When the maximum value of “k1\_def” is reached***

***Proposal 16: “1-shot enhanced Type 3 CB”, is constructed with HARQ processes as basis and its contents are:***

* ***Either: all requested HARQ process IDs within a pre-determined time duration, td, with a starting point in time t0, e.g. t0: X sub(slots) prior to DCI, or***
* ***All requested HARQ Process IDs indicated in the DCI***

***Proposal 17: Only one Enhanced Type 3 CB size should be supported/requested within a given time duration.***

***Proposal 18: For the “one-shot triggering of HARQ-ACK re-transmission on a PUCCH resource other than enhanced Type 2 or (enhanced) Type 3 HARQ-ACK CB (second option of the working assumption):***

* ***support the transmission of only a single “cancelled HARQ-ACK CB” within a given time window***
* ***support gNB request for “UE Indication of Cancelled HARQ CB” in DCI 1\_1 or DCI 1\_2 with an extra bit.***
* ***support the indication of the UE of “cancelled HARQ” in UCI, only upon gNB request; “UE indication of cancelled HARQ” bit set to 1 upon existence of at least 1 “cancelled HARQ CB”.***

***Proposal 19: Support automatic transmission of a single cancelled HARQ ACK info at retransmission of PUSCH cancelled by DCI 2\_4.***

***Provided that DCI 0\_x indicates same NDI and HARQ Process ID for both cancelled and retransmitted PUSCH.***

***In case canceled UCI contains CSI, SR and HARQ payload, only HARQ payload is automatically transmitted.***

***No support for new UCI multiplexed in the retransmitted PUSCH.***

***Proposal 20: Do not support partial automatic (re)transmission of cancelled HARQ bits.***

***Proposal 21: Support automatic (re)transmission of 1 single dropped LP HARQ-ACK CB. Automatic (re)transmission at the same PRI as the one for the initial PUCCH allocation; PRI allocation valid for up to N slots.***

***Proposal 22: RAN 1 to study joint configuration of***

* ***automatic (re)transmission of cancelled/dropped HARQ-Ack,***
* ***“1-shot Enhanced Type 3 HARQ feedback”,***
* ***PUCCH carrier switching (in case of more than 1 PUCCH CCs)***

***Or of any combination of the above.***

***Proposal 23: Upon joint configuration of:***

* ***“automatic (re)transmission of cancelled/dropped HARQ-Ack”***
* ***“1-shot HARQ (re)transmission”***
* ***“PUCCH carrier switching”***

***Or of any combination of the above, execution of “automatic (re)transmission of dropped or cancelled HARQ-ACK” starts immediately after HARQ-ACK dropping or cancellation and it stops:***

1. ***when appropriate PUCCH resource for the transmission of the single dropped LP HARQ-ACK is found, or***
2. ***upon reception of PUSCH allocation (DCI 0\_x) with same NDI and HARQ ID(s) as the allocation of the initially cancelled PUSCH via DCI 2\_4 , or***
3. ***when a request for “1-shot HARQ (re)transmisison” is received, or***
4. ***when a “PUCCH-Carrier Switch Command” is received in DCI (in case of more than 1 PUCCH CCs)***
5. ***when the validity of the PUCCH Resource for the single dropped LP HARQ CB expires.***

***Proposal 24: For semi-static configured PUCCH carrier switch, use Pcell or PScell as the reference CC to interpret the K1 value and determine a reference slot for PUCCH transmission, then use Pcell or PScell as reference CC to interpret the carrier switch time pattern to determine the target cell for PUCCH transmission. If the target cell numerology is larger than Pcell or PScell, the earliest actual slot on the target cell which falls into the reference slot is used to transmit the PUCCH.***

***Proposal 25: In PUCCH power control, support separate P0 configuration for each of the cells with PUCCH carrier switch enabled.***

***Proposal 26: In PUCCH power control, support accumulating closed loop power control commands only within the same target cell by reusing Rel-15 procedure. Don’t support accumulating power control commands across cells.***

***Proposal 27: Support to use MAC-CE to signal PUCCH spatial relation on Scell(s) with PUCCH carrier switch. FFS details of such MAC-CE signalling including how to reduce the MAC-CE overhead.***

***Proposal 28: RAN1 to study then decide whether and how to support the following joint operations.***

* ***Joint operation of PUCCH carrier switch, parallel PUCCH/PUSCH transmission, and intra-UE multiplexing.***
* ***Joint operation of PUCCH carrier switch with PUCCH repetition.***
* ***Joint operation of PUCCH carrier switch with SPS A/N deferral.***

***Proposal 29: For sub-slot based Type-1 HARQ-ACK codebook construction in NR Rel-17, support TDRA grouping and pruning based on UL sub-slots.***

* ***More specifically, for each UL sub-slot*** $n\_{U}-K\_{1,k}$***, UE determines a set of TDRA candidates that ends in the UL sub-slot, and perform TDRA pruning based on the Rel-15 approach.***

### R1-2107397 Discussion on UE feeback enhancements for HARQ-ACK CMCC

***Proposal 1: PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells.***

***Proposal 2: The length of PUCCH switching configuration table equals to*** $N\_{slot}^{frame,μ}$ ***of the Pcell/PScell.***

***Proposal 3: The reference slot (like slot0 in the table) is based on Pcell/PScell.***

***Proposal 4: The corresponding slot number of other Scells is calculated according to slot offset configuration given by*** $N\_{slot, offset}^{CA}$ ***(TS38.211, 4.5 Carrier aggregation)***

### R1-2107443 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics

Proposal 1: SPS HARQ-ACK deferral is configured per SPS configuration

Proposal 2: Alt. 2 for deferral condition is not supported.

Proposal 3: Alt. 1A for deferral condition is supported.

Proposal 4: To determine deferral of SPS HARQ-ACK in an initial slot/sub-slot, following alternative can be considered:

* Alt. 2: Defer if there is no available symbol for an uplink transmission obtained in case of UL multiplexing in the initial slot/sub-slot as if there are only semi-statically scheduled PUCCH transmission and PUCCH only for the SPS HARQ-ACK.

Proposal 5: For an initial slot/sub-slot of deferral, deferral procedure doesn’t make any changes on a result of UL multiplexing in the initial slot/sub-slot.

Proposal 6: To determine availability of candidates for target slot, the same assumption used to determine deferral can be considered.

Proposal 7: For SPS HARQ-ACK deferral, the target slot of deferral procedure is a slot/sub-slot where next SPS PUCCH occasion of corresponding SPS configuration is.

* FFS: whether to use SPS PUCCH occasion for different SPS configuration.

Proposal 8: Confirm above working assumption.

Proposal 9: For SPS HARQ-ACK deferral, the target slot of deferral procedure is next available slot/sub-slot n+k where reference PDSCH occasion is received in slot n and k is element of a set K.

* Reference PDSCH occasion is one of PDSCH occasion corresponding to deferred HARQ-ACK.
* The set K is union of configured sets of PDSCH-to-HARQ-ACK feedback timings.
* FFS: How to determine reference PDSCH for deferral

Proposal 10: Support type-3 HARQ-ACK codebook only for a part of HARQ process IDs and/or serving cells (e.g. the serving cells/HARQ process IDs configured for SPS PDSCH).

Proposal 11: if type-3 HARQ-ACK codebook is supported only for SPS PDSCH, it can be considered to separate the codebook for dynamic PDSCH and for SPS PDSCH.

Proposal 12: Support enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size for re-transmission of cancelled HARQ-ACK if necessary.

Proposal 13: For construction of the enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size, following options can be considered:

* Option 1: type-3 HARQ-ACK codebook with subset of entire HARQ processes.
	+ Multiple subset of HARQ processes can be configured by RRC signaling.
	+ A subset of HARQ processes can be indicated in a DCI triggering type-3 HARQ-ACK codebook for HARQ-ACK codebook construction.
* Option 2: type-3 HARQ-ACK codebook with HARQ processes used in SPS PDSCH reception.

Proposal 14: For triggering method enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size, following options can be considered on the top of current framework. :

* + Option 1: triggering DCI indicates a subset of HARQ processes for the HARQ-ACK codebook. Existing DCI field (e.g., One-shot HARQ-ACK request field) can be re-used or extended for indicating a subset of HARQ process.
	+ Option 2: RNTI scrambling CRC of DCI format can indicates how to construct type-3 HARQ-ACK codebook.

Proposal 15: For type-3 HARQ-ACK codebook only for SPS PDSCH, priority handling can be considered.

Proposal 16: Take interpretation 2 or 3 as one-shot triggering framework.

Proposal 17: Adopt above working assumption to sub-slot repetition if the working assumption is confirmed.

Proposal 18: Discuss whether to apply above working assumption to semi-static PUCCH and how repetition factor is applied in the case of UL multiplexing with semi-static PUCCH resource.

Proposal 19: Use 3-bit PRI field or adopt dedicated DCI field to indicate switched carrier.

Proposal 20: For HARQ-ACK PUCCH for SPS PDSCH itself, dynamic PUCCH carrier switching is not supported.

* Carrier indication in activation DCI is ignored for SPS PDSCH without corresponding DCI

Proposal 21: For PUCCH carrier switching based on semi-static indication, the PDSCH to HARQ-ACK offset k1 is interpreted based on the numerology of original PUCCH cell (i.e. primary cell).

Proposal 22: For PUCCH carrier switching based on semi-static indication, target PUCCH resource in the target cell can be determined with following:

* PRI or resource set ID is re-used in the target carrier.
* First UL slot overlapped with original UL slot or a symbol of original PUCCH can be used as target UL slot in the target carrier.

### R1-2107472 UE feedback enhancements for HARQ-ACK ETRI

Regarding HARQ-ACK deferral,

**Proposal 1: The SPS HARQ-ACK deferral can be configured per SPS configuration.**

**Proposal 2**: **In addition to semi-static DL/SSB/CORESET0, some of semi-static FL symbols can be invalid by configurations.**

**Proposal 3**: **The deferred SPS HARQ-ACK bits are prepended in the Type1 HARQ codebook.**

**Proposal 4**: **Further study the Type2 HARQ codebook if deferred SPS HARQ-ACK bits are present**

**Proposal 5: If being repeated, the PUCCH is transmitted within the latest effective time window in the HARQ codebook if applicable.**

Regarding Type-3 HARQ-ACK codebook,

**Proposal 6**: **The size of the enhanced Type-3 HARQ-ACK codebook can be determined by at least activation/release DCI for SPS.**

**Proposal 7**: **The size of the enhanced Type-3 HARQ-ACK codebook can be determined by at least activated serving cells.**

**Proposal 8**: **The reference time to derive HARQ-ACK codebook is introduced in terms of a (sub) slot, where the HARQ-ACK of relevant HARQ processes are involved.**

**Proposal 9**: **If M=2 type-3 HARQ-ACK codebooks are enabled, then the distinct RNTI can be used to generate a legacy one or an enhancement one.**

Regarding PUCCH carrier switching,

**Proposal 10: SPS HARQ-ACK deferral may not be configured if PUCCH cell switching is enabled.**

**Proposal 11: The maximum number of PUCCH cell can be the number of configured serving cells.**

**Proposal 12: Further study to change a serving cell for PUCCH transmission with repetition.**

**Proposal 13: Any UCI type can support the PUCCH carrier switching if supported.**

### R1-2107491 On UE feedback enhancements for HARQ-ACK MediaTek Inc.

1. ***Support the dynamic PUCCH carrier switching for scheduled PUCCH and support the semi-static PUCCH cell timing pattern for configured SPS HARQ-ACK PUCCH.***
2. ***Support of the dynamic indication in the triggering DCI by including a new DCI field for the carrier switching indication***
3. ***For PUCCH carrier switching based on semi-static PUCCH cell timing pattern, the reference numerology for the timing pattern is configurable by the gNB.***
4. ***For PUCCH carrier switching based on semi-static PUCCH cell timing pattern, the granularity of the timing pattern UL slot of the reference numerology.***
5. ***Define two levels of PUCCH configuration, “per PUCCH group” and “per PUCCH carrier”.***
6. ***Each cell carrying PUCCH has its own TPC configuration (PUCCH-PowerControl) and has its own TPC loop. When switching the PUCCH carrier, UE changes the power control parameters to use the ones associated to the new PUCCH carrier.***
7. ***Explore the signalling and the support of one-shot triggering:***

***Alt-1: a new DCI field to be introduced for signalling. E.g. a new single bit triggers re-sending, i.e., concatenation or e.g. slot index(-ices) pointing back in time selecting the codebook(s) that are requested for resending***

***Alt-2: existing DCI field is reused for signalling. E.g. pre-configured special value of K1 or combination of K1 and another field (e.g. HARQ) triggers re-sending, i.e. concatenation. Another possibility is to define a pre-configured special value of HARQ process ID (or special value in another field different from K1) that triggers re-sending, i.e. concatenation.***

***Alt-3: implicit signalling is used (based e.g. on RNTI, search space)***

***Alt-4: the sending is triggered implicitly by the earliest PUCCH that is transmitted next or after the current slot.***

1. ***The PHY priority in the triggering DCI triggers only HARQ-ACK of the same priority.***
2. ***Support enhanced Type 3 HARQ-ACK CB for the LP-HARQ and the one-shot triggering for HP-HARQ.***
3. ***An RRC configuration should be defined to enable/disable HARQ-ACK deferral per PUCCH cell group***
4. ***k1eff to not exceed the maximum value in the set of configured K1 values.***

### R1-2107583 Design aspects for the agreed HARQ feedback enhancements Intel Corporation

**Proposal 1-1**

* *SPS HARQ-ACK deferring is enabled/disabled by semi-static signaling per SPS configuration*

**Proposal 1-2**

* *Whether a SPS HARQ feedback should be deferred is determined solely based on semi-static configurations upon reception of SPS activation for any of the PDSCH activated by this DCI*
	+ *I.e., dynamic UCI multiplexing/presence is not considered*
* *Support additional configuration of SPS PUCCH resource with activated deferring, which is used for hypothesis testing on mapping SPS HARQ-ACK bits for a given initial/deferred slot/sub-slot*

**Proposal 1-3**

* *For the activated SPS HARQ-ACK deferral, the maximum k1 value is configured by RRC*

**Proposal 1-4**

* *The working assumption on handling SPS HARQ process ID collision can be confirmed with clarification that “received PDSCH” cover both skipped and transmitted SPS PDSCH*

**Proposal 1-5**

* *Existing procedures for deferred SPS HARQ-ACK multiplexing on UCI are reused with additional handling of inclusion of a non-contained k1 value to the k1 set for Type 1 CB construction*

**Proposal 2-1**

* *Support triggering of Type 3 CB additionally by DCI format 1\_2*
* *Support triggering of eType 3 CB by DCI formats 1\_1 and 1\_2*

**Proposal 2-2**

* *Support triggering of enhanced Type 3 CB transmission by both*
	+ *DCI scheduling other PDSCH*
	+ *DCI not scheduling other PDSCH*

**Proposal 2-3**

* *Support combination of RRC configuration and triggering DCI content for constructing enhanced Type 3 CB, i.e. support multiple Type 3 CB sizes*
	+ *The different CB sizes are resulted from different assumption on*
		- *cells to be reported*
		- *SPS-only or all HARQ processes*
		- *priority*
		- *etc.*

**Proposal 2-4**

* *When Type 3 or eType 3 CB is triggered by a DCI, the priority field in the DCI, if present, is used to determine PUCCH priority carrying the CB*

**Proposal 2-5**

* *Support enhanced Type 3 CB construction from a subset of HARQ processes based dynamic indication in DCI triggering the enhanced Type 3 CB*
	+ *FFS details*

**Proposal 2-6**

* *For handling HARQ feedbacks which process IDs are not included into the sub-set requested by a eType 3 CB trigger*
	+ *Option 1: a UE is not expected the sub-set of HARQ IDs to not contain the new HARQ feedback*
	+ *Option 2: a UE drops the HARQ feedback if the corresponding process ID is not contained in the triggered sub-set*

**Proposal 3-1**

* *For sub-slot PUCCH repetition, introduce a mechanism of skipping UL symbols during repetitions mapping*
	+ *Alt.1: X-symbol gap*
	+ *Alt.2: Y-sub-slot gap*
	+ *Alt.3: Invalid symbol pattern*

**Proposal 3-2**

* *The number of REs for UCI carrying HARQ-ACK on PUSCH is scaled with the number of PUCCH repetitions overlapped with a PUSCH*
	+ *FFS details*

**Proposal 3-3**

* *RAN1 uses the same mechanism for dynamic indication of the number of PUCCH repetitions for slot-based and sub-slot-based operation, by aligning with decisions made in CovEnh*

**Proposal 4-1**

* *For dynamic PUCCH carrier indication in DCI, the definition of PUCCH Resource ID (PRI) is extended by indicating a pair of {PUCCH resource, PUCCH carrier}*

**Proposal 4-2**

* *For dynamic PUCCH carrier indication in DCI, limit the UCI information for switching to HARQ-ACK and SR (when multiplexed with HARQ-ACK)*

**Proposal 4-3**

* *If a time pattern for PUCCH for semi-static HARQ-ACK is not provided, the semi-static HARQ-ACK is multiplexed with dynamic HARQ-ACK on the carrier indicated for dynamic HARQ-ACK*
	+ *FFS if a time pattern for PCCH for semi-static HARQ is provided*

### R1-2107639 HARQ enhancements for IIoT and URLLC InterDigital, Inc.

***Proposal 1:*** *Support PHY priority handling for the enhanced Type 3 HARQ CB.*

***Proposal 2:*** *The DCI triggering enhanced Type 3 CB can indicate the priority of the Type 3 HARQ CB.*

***Proposal 3:*** *Support at least**a non-scheduling DCI triggering the one-shot HARQ-ACK retransmission.*

***Proposal 4:*** *The UE expects the same PUCCH carrier indication for all the scheduled A/Ns associated with the same HARQ-ACK codebook.*

***Proposal 5:*** *The UE selects the PUCCH carrier based on the carrier index in case more than one PUCCH carrier are available.*

### R1-2107732 HARQ Feedback Enhancements for URLLC Apple

**Proposal 2-1: to control feedback overhead, the presence of NDI and utilization of CBG based feedback can be separately configured for code states in the “priority indicator”.**

**Proposal 2-2: to control feedback overhead, HARQ process IDs can be grouped, one group is associated with the high priority, another is associated with the low priority.**

**Proposal 3-1: the number of PUCCH cells is limited to 2 for both dynamic indication and semi-static configuration.**

**Proposal 3-2: semi-static time pattern for PUCCH cells provides potential resources for PUCCH transmission. Transmitting PUCCH over a potential resource is subject to the same rules for PUCCH over a single CC case, in terms of semi-static SFI and dynamic SFI and dynamic scheduling.**

**Proposal 3-2: nested PUCCH symbols are not allowed for PUCCH carrier switching.**

**Proposal 3-3: out-of-order HARQ-ACK remains forbidden for non-mTRP scenarios with PUCCH carrier switching.**

### R1-2107791 UE feedback enhancements for HARQ-ACK Sharp

**Proposal 1:**

* The deferring of SPS HARQ-ACK dropped due to TDD specific collisions is configured by RRC per SPS configuration.

**Proposal 2:**

* **‘NACK skipping’ for (skipped) SPS PDSCH is supported**.

**Proposal 3:**

* **‘HARQ bundling’ for (non-skipped) SPS PDSCH is supported**.

**Proposal 4:**

* **PUCCH repetition for PUCCH formats 0 and 2 is also supported for slot based PUCCH repetition in Rel-17**.

**Proposal 5:**

* **Sub-slot based PUCCH repetition for other UCI types (than HARQ-ACK) is also supported**.

**Proposal 6:**

* Clarify the necessary modifications on Type-3 HARQ-ACK codebook for adoption in Rel-17 URLLC operation first, e.g., handling of different priorities.

### R1-2107833 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.

**Proposal 1: The SPS HARQ-ACK deferral should be configured per SPS configuration.**

**Proposal 2: The PUCCH which carries the deferred HARQ-ACK feedback should be the first instance of PUCCH which does not collide with any invalid or downlink symbols and this PUCCH resource should not be restricted to the PUCCH for SPS only.**

**Proposal 3: Only if the intra-slot deferral cannot be achieved, and then inter-slot deferral should be considered.**

**Proposal 4: To determine an available PUCCH resource for conveying the deferred SPS HARQ-ACK,semi-static flexible symbol(s) could be used for transmitting the deferred HARQ-ACK feedbacks.**

**Proposal 5: The *k1def,max*. should be the maximum k1 value of the configured K1 set.**

**Proposal 6: The value of *k1eff* should be limited to one of the existing k1 values in the configured K1 set**

**Proposal 7: Enhanced Type 3 HARQ-ACK CB with smaller size in Release-17 should be supported.**

**Proposal 8： ACK skipping and/or NACK skipping mechanism for shorter SPS periodicity or multiple SPS configurations should be supported.**

**Proposal 9： HARQ bundling/compression should be supported for HARQ-ACK payload reduction and N-bits SPS HARQ-ACK should be bundled into one single bit using logical ‘OR’.**

**Proposal 10: The PDSCH TDRA grouping should be performed per sub-slot.**

### R1-2107851 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.

Proposal 1: Support option 1, i.e. joint RRC configuration of the SPS HARQ-ACK deferral per PUCCH cell group.

Proposal 2: Support Alt. 1. Deferral only, if the SPS HARQ-ACK in the initial slot/sub-slot cannot be transmitted as the resulting PUCCH resource for transmission using the PUCCH by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN is not valid, where the “invalid” symbol stands for semi-static DL or SSB symbol.

Proposal 3: For definition of “next available PUCCH resource”,

* The “next available PUCCH resource” is the PUCCH resource in the earliest sub-slot/slot after the K1 indicated sub-slot/slot considering at least following conditions:
	+ **Maximum effective K1 limitation is configured per SPS configuration.**
	+ **the PUCCH for deferred HARQ-ACK transmission in the sub-slot/slot has no collision with any semi-static DL symbol and SSB symbol.s**
* **Keep the UE behavior for deferred SPS HARQ-ACK aligned with that in initial slot/sub-slot.**
	+ **Candidate PUCCH resource for non-deferred SPS HARQ-ACK is PUCCH resource configured by SPS-PUCCH-AN-List-r16 or n1PUCCH-AN.**
	+ **Intra-UE multiplexing is considered when determining target deferral slot/sub-slot.**

Proposal 4: For HARQ-ACK CB construction for SPS HARQ-ACK deferring

* **If UE reports only deferred SPS HARQ-ACK information in the HARQ-ACK CB, simply order deferred SPS HARQ-ACK bits.**
* **If UE reports non-deferred HARQ-ACK information and deferred SPS HARQ-ACK information in the HARQ-ACK CB, deferred SPS HARQ-ACK bits are appended after non-deferred bits.**
* **For ordering deferred SPS HARQ-ACK bits, Rel.16 SPS HARQ-ACK bit order principle as in clause 9.1.2 of TS38.213 can be the baseline, i.e. based on serving cell index, SPS configuration index, SPS PDSCH slot index.**

**Proposal 5: Confirm the working assumption for HARQ-ACK retransmission.**

**Proposal 6: If DCI 1\_1 can be simultaneously configured with one-shot HARQ-ACK feedback and priority indicator field existing in DCI 1\_1, type 3 HARQ-ACK CB consists of all HARQ process IDs regardless of priority indicated for each HARQ-ACK bit. The priority of the HARQ-ACK PUCCH is determined by physical priority indicator in the triggering DCI.**

**Proposal 7: Support the configuration with more than one enhanced type 3 HARQ-ACK CBs with smaller size. Triggering DCI indicates which type 3 HARQ-ACK CB to be reported.**

**Proposal 8: Support one-shot triggering of HARQ-ACK retransmission for all HARQ-ACKs in a time window.**

**Proposal 9: Support slot-based PUCCH repetition for PUCCH formats 0 and 2.**

**Proposal 10: Do not support sub-slot based PUCCH repetition for SR and CSI.**

Proposal 11: Support sub-sot based TDRA grouping/pruning for type 1 HARQ codebook for sub-slot based HARQ-ACK feedback in Rel.17.

**Proposal 12: A dedicated DCI field is used to indicate target PUCCH cell. UE doesn’t expect overlapping of HARQ-ACK slots indicated by DCI on different PUCCH cells.**

**Proposal 13: The dedicated target PUCCH cell is not applied for SPS HARQ-ACK if the field exists in the activation DCI. A default cell (e.g. PCell/PScell/PUCCH-Scell) is determined as the target PUCCH cell for SPS PDSCHs of all SPS configurations.**

**Proposal 14: If there is overlapping of SPS HARQ-ACK slot and dynamic HARQ-ACK slot on different PUCCH cells, SPS HARQ-ACK will be multiplexed to the dynamic HARQ-ACK slot on the target cell indicated by DCI. SPS HARQ-ACK CBs on other cells are appended after the original type 1/2 HARQ-ACK CB generated for the dynamic HARQ-ACK slot.**

**Proposal 15: For semi-static PUCCH carrier switching, the PUCCH cell timing pattern is defined based on the numerology of PCell/PScell/PUCCH-Scell. Slot-level granularity indication based on TDD configuration length will be applied.**

**Proposal 16: If SCS of target cell is different from the SCS of PCell/PScell/PUCCH-Scell,**

* **If SCS of target cell is larger than SCS of PCell/PScell/PUCCH-Scell, the slot overlapping with the PUCCH slot on PCell/PScell/PUCCH-Scell is the PUCCH slot after PUCCH carrier switching.**
* **If SCS of target cell is smaller than SCS of PCell/PScell/PUCCH-Scell, the first slot overlapping with the PUCCH slot on PCell/PScell/PUCCH-Scell is determined as the PUCCH slot after PUCCH carrier switching.**

### R1-2107917 UE feedback enhancements for HARQ-ACK Xiaomi

*Proposal 1: When multiplexing in initial slot is possible, HARQ-ACK should not be deferred.*

*Proposal 2: we support option 2, k1def*  *should be counted based on UL and S slots according to semi-static TDD pattern.*

*Proposal 3: Same SCS of PUCCH carriers within a PUCCH cell group should be highest priority, and other different SCS decrease priority from high SCS to low SCS.*

*Proposal 4: The case of multiplexing and collision should not be considered on the switching PUCCH carrier.*

*Proposal 5: Do not support out-of-order trigger and out-of-order HARQ feedback when switching PUCCH carrier.*

*Proposal 6: Dynamic repetition indication mechanism in CE PUCCH enhancement can be directly applied to sub-slot based PUCCH repetition.*

*Proposal 7: It is unnecessary to support slot-based PUCCH repetition for format 0 and 2.*

*Proposal 8: Support NACK skipping for skipped SPS PDSCH and support ACK skipping for non-skipped SPS PDSCH.*

*Proposal 9: Support using alt 4 HARQ bundling / compression combined with alt 1 and alt 3 together to achieve the most significant gain.*

*Proposal 10: Dynamic indication of skipped SPS is not necessary considering a tradeoff between small gains and large standard impacts.*

### R1-2108152 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.

* *Proposal 1: When enhanced Type-3 HARQ-ACK CB with smaller size is used for at least HARQ-ACK retransmission, the following aspects should be further enhanced.*
	+ *Support of DCI format 1\_2 triggering enhanced Type-3 HARQ-ACK CB, Determination on PHY priority of enhanced Type-3 HARQ-ACK CB, and Inclusion of HARQ-ACK of SPS release DCI*
* *Proposal 2: We propose to support Alt-2, i.e., the HARQ-ACK codebook to be re-tx is explicitly indicated in the triggering DCI for one-shot triggering (by a DL assignment) of HARQ-ACK re-transmission on a PUCCH resource for Rel-17 URLLC/IIoT.*

### R1-2108162 UE feedback enhancements for HARQ-ACK CAICT

***Proposal 1: SPS HARQ-ACK deferral is configured per SPS configuration.***

***Proposal 2: SPS HARQ-ACK is deferred if initial PUCCH includes invalid symbol(s) which the initial PUCCH is determined according to the current UCI multiplexing behavior from the configuration of SPS-PUCCH-AN-List-r16 or n1PUCCH-AN, n1PUCCH-AN, multi-CSI-PUCCH-ResourceList.***

***Proposal 3: If gNB supports PUCCH blind detection assuming DCI is missed by UE, SPS HARQ-ACK needs not to be deferred if it is transmitted in the initial PUCCH which is decided from PUCCH-ResourceSet. Otherwise, SPS HARQ-ACK should be deferred even if it is transmitted in the PUCCH from PUCCH-ResourceSet.***

***Proposal 4: SPS HARQ-ACK is possible to be deferred to one PUCCH other than the initial PUCCH in the initial slot/subslot.***

***Proposal 5: To decrease the deferred SPS HARQ-ACK impacts on the UCI in the initial PUCCH, if the initial PUCCH is invalid, UCI multiplexing procedure in the initial slot/subslot assumes*** $N-N\_{2}$ ***bits of SPS HARQ-ACK is to be transmitted while*** $N\_{2}$ ***bits of SPS HARQ-ACK is deferred to the following slots/subslots,***

* ***wherein,*** $N$ ***is the bit width of SPS HARQ-ACK in the initial PUCCH.*** $N\_{1}$ ***bits of SPS HARQ-ACK within the*** $N$ ***bits is configured deferrable,*** $N\_{1}\leq N$***. The value of*** $N\_{2}$ ***is the minimum value that results in at least one valid PUCCH or PUSCH for the UCIs in the “initial PUCCH” according to the existing UCI multiplexing rules,*** $N\_{2}\leq N\_{1}$***.***

***Proposal 6: gNB configures whether UL symbols indicated by SFI could be valid symbols or not when deciding available PUCCH.***

***Proposal 7: The next available PUCCH is the earliest one within the PUCCHs decided within available symbols and the PUCCHs which was to be transmitted according to Rel.16 procedure.***

***Proposal 8: To decide the number of contiguous UL symbols for available PUCCH transmission, PUCCH parameters configured by n1PUCCH-AN/SPS-PUCCH-AN-List-r16 could be reused, or special PUCCH configuration for deferred HARQ-ACK could be considered.***

***Proposal 9: Semi-static configured PUCCH transmission according to SPS-PUCCH-AN-List-r16 or multi-CSI-PUCCH-ResourceList could be used as available PUCCH.***

***Proposal 10: gNB configures whether PUCCH transmission scheduled for dynamic HARQ-ACK could be used as available PUCCH or not.***

***Proposal 11: New bit field in DCI to indicate the target cell is acceptable if majority companies think it is feasible in Rel.17.***

***Proposal 12: Consider overlapped slots in other BWPs which includes SPS HARQ-ACK when constructs HARQ-ACK codebook in the target BWP.***

***Proposal 13: For Alt.1, PUCCH switching for SPS HARQ-ACK is achieved by dynamic /PUSCH scheduling in another cell.***

***Proposal 14: For Alt 2C, the time domain pattern is based on one reference slot and the reference slot corresponds to the lowest SCS of candidate BWPs.***

***Proposal 15: Construct HARQ-ACK codebook based on the reference slot and the numerology of reference BWP rather than based on the actual slot which the PUCCH is transmitted.***