**3GPP TSG-RAN WG1 Meeting #104-eR1-21XXXXX**

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

**Agenda item: 8.3.1.1**

**Source: Moderator (Nokia)**

**Title: Moderator summary #X on HARQ-ACK feedback enhancements for NR Rel-17 URLLC/IIoT (AI 8.3.1.1)**

**Document for: Discussion and Decision**

# Introduction

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

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

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

**This document is structured as follows:**

* Sections 2 to 7 include the topics to be specified or at least further studied based on previous agreements, including sub-sections for the related email discussion rounds
* Section 8 describes further suggested enhancements by different companies not directly related to the agreed study focus based on previous RAN1 agreements
* There are two appendices, one summarizing the companies’ proposals for easier referencing and one containing the agreements reached so far.

# SPS HARQ-ACK dropping for TDD

In this section, the proposed Rel-17 enhancements to prevent SPS HARQ-ACK dropping for TDD operation are summarized. During RAN1#103-e, there had been a down-selection to two alternatives to be further consider:

*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*

**Moderator comment: Option 2 / Type 3 CB enhancements for SPS are handled together with Type 3 type of re-transmission enhancements as part of the ‘Retransmission of cancelled HARQ’ in Sec. 5.**

**Option 1: Deferring HARQ-ACK until a first available PUCCH – 26x Yes, 1x FFS**

* **Yes (26):** ZTE [1], OPPO [2], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Ericsson [4], CAICT [5], CATT [6], vivo [7], Intel [9], Nokia [10], Spreadtrum [11], Sony [12], LGE [13], China Telecom [14], TCL [15], NEC [16], APT [17], Moto/Len [18], Panasonic [19], CMCC [20], Xiaomi [22], Samsung [23], Sharp [27], DOCOMO [28], WILUS [29]
* **FFS (1):** ETRI [21]

**Proposed details on Option 1:**

* What PUCCH carrying SPS HARQ-ACK / which SPS HARQ-ACK bits are subject to deferral
	+ Deferral only, in case there is not any available symbol in a slot / sub-slot for PUCCH transmission: Ericsson [4]
	+ The deferral is only possible for a codebook only including SPS HARQ: Ericsson [4]
	+ Deferral only, if the initial resource based on *SPS-PUCCH-AN-List-r16* is not valid: CATT [6], China Telecom [14] (SS-DL symbols or SSB), CMCC [20] (SS-DL/SSB symbols), DOCOMO [28] (for any PUCCH dropping case not just SS-DL/SSB), WILUS [29] (SS-DL & flexible symbols)
	+ For a given UL slot, the untransmitted HARQ-ACKs of the SPS PDSCHs before the DL slot corresponding to the indicated K1 are deferred to the given UL slot: OPPO [2]
	+ A maximum of N HARQ-ACK bits is deferred (N is FFS): Sony [12], TCL [15], NEC [16], ETRI [21]
	+ To limit the size, configure a subset of SPS PDSCH config for deferral: Moto/Len [18]
* Definition of next available PUCCH
	+ Taking only semi-static DL & SSB symbols as invalid into account: ZTE [1], Ericsson [4], CATT [6], vivo [7], Spreadtrum [11], TCL [15], CMCC [20]
		- Determination determined by the initial PUCCH: ZTE [1]
	+ In addition, different options discussed by multiple companies including semi-static flexible symbols (i.e. valid symbols only UL symbols not colliding with SSB) as well as taking SFI into account.
	+ gNB configures the handling of semi-static flexible symbols: CAICT [5]
	+ Set of UL slots (and related k1) is configured: OPPO [2]
	+ Additional configuration of invalid UL symbols / slot/sub-slots: Ericsson [4]
	+ Deferral k1 should be part of the configured K1 set: Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], CATT [6], vivo [7], TCL [15]
	+ Deferral limited by the maximum k1 value: Ericsson [4], vivo [7], TCL [15], DOCOMO [28]
	+ Dereral limited by a configurable number of slots per SPS configuration: APT [17]
	+ Deferal limited by a configurable maximum HARQ-ACK delay (e.g. per SPS config): Moto/Len [18]
	+ Taking a maximum payload size (e.g. configured) for different slot offsets into account: Xiaomi [22]
	+ Increase k1 by 1 or by P (P=SPS periodicity): WILUS [29]
* PUCCH resource determination:
	+ Using *SPS-PUCCH-AN-List-r16* resources only: Ericsson [4], CAICT [5], CATT [6] (FFS if the PUCCH from SPS from delayed or both, initial and delayed are candidates), Nokia [10], LGE [13] (of the same SPS configuration), APT [17], Panasonic [19], CMCC [20], WILUS [29]
	+ Using PUCCH resources from *sps-PUCCH-AN-List-r16* and *PUCCH-ResourceSet*: ZTE [1], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], vivo [7], Sony [12], China Telecom [14], TCL [15], NEC [16], CMCC [20], Samsung [23], DOCOMO [28]
	+ Using *multi-CSI-PUCCH-ResourceList*: CAICT [5]
	+ Configure additional PUCCH resources for defering (incl. potentially separate k1): Intel [9], Nokia [10], CMCC [20], DOCOMO [28] (REs of the PUCCH resource)
	+ Following Rel-16 mechanism: OPPO [2]
* Other proposed conditions on the PUCCH resource selection:
	+ Depending on the size of the HARQ-ACK codebook: ZTE [1], Ericsson [4]
	+ Number of PUCCH symbols is not less than the ones from the original PUCCH: ZTE [1]
	+ Selected PUCCH resource is the one with the earliest ending symbol: ZTE [1], CAICT [5], Spreadtrum [11], TCL [15] (.. the first)
* Multiplexing of deferred SPS HARQ-ACK with another HARQ-ACK codebook:
	+ gNB configures if multiplexing is possible with dynamic HARQ-ACK: CAICT [5]
	+ Append deferred SPS HARQ-ACK bits to another, ‘newer’ HARQ-ACK codebook: ZTE [1] (only if not contained in Type 1 CB already), NEC [16], Moto/Len [18], DOCOMO [28]
	+ Include SPS HARQ-ACK bits to Type 1 CB if possible and append the rest: ZTE [1], vivo [7], Nokia [10]
	+ For SPS HARQ only, the Rel-16 mechanism can be reused: vivo [7], Nokia [10], DOCOMO [28]
	+ For Type 2 CB, the SPS HARQ-ACK bits can be appended reusing the Rel-16 mechanism of SPS HARQ-ACK ordering: vivo [7], Nokia [10]
	+ CMCC [20]: Assuming T = periodicity of UL/DL config or periodicity of periodically configured PUCCH resource
		- For Type 1 CB: union of two K1 sets – the set K1 and the set ‘K1+T-1’ (K1 set offset by the deferred time T minus 1)
		- For Type 2 CB: append all SPS bits from slot n-k+T+1 to n-k, where k is the k1 value for the SPS configuration (based on the activation DCI)
* Other aspects:
	+ Only a single deferral is possible: Ericsson [4] – further deferral possible: DOCOMO [28]
	+ Out-of-order considerations due to deferred SPS HARQ-ACK needed: vivo [7], LGE [13]
	+ Limitation in the deferral limited by the starting symbol of upcoming PDSCH occasion corresponding to same HARQ process ID: LGE [13]

## 2.1 First round of email discussions

*Moderator comment:*

Based on the input contributions to this meeting, **26 companies discuss in their contributions how to support Option 1 of enabling deferral of SPS HARQ in their contribution (with 1 company indicating FFS overall)**. But the input is somehow rather diverse including things such as:

* What are the conditions for SPS HARQ-ACK to be applicable for deferral?
* How to select the slot (i.e, k1) for deferred SPS HARQ-ACK transmission (incl. related restrictions) and interaction with the TDD configuration.
* Details on the PUCCH resource reselection (and related restrictions)
* Multiplexing of deferred SPS HARQ-ACK and non-deferred SPS & DG PDSCH HARQ-ACK
* …

During the GTW session on Mon. Jan 25th 2021, the following agreement on the overall support of Option 1 was made:

*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*

Clearly it will not be possible to discuss all of these issues (and find solutions for all of them) during RAN1#104-e. Therefore, the following **focus at least for the first phases of the email discussion is proposed**:

1. Discuss (with the intend to clarify / agree) when an SPS HARQ-ACK is applicable for deferral
	* This seems to be essential as first step and will bring clarity also to other discussions such as TDD configuration interaction when discussing what the next available PUCCH is.
2. Discuss restrictions in terms of slot/sub-slot offset on deferral (as had been mentioned by several companies during the GTW call)
3. Discuss (with the intend to clarify / agree) on the multiplexing of deferred SPS HARQ-ACK on PUCCH with other UCI (such as non-deferred SPS HARQ, HARQ of scheduled PDSCH, SP-CSI on PUCCH, SR, …)
	* This will also have an effect on the definition of the ‘next available PUCCH’ – as different cases may need to be considered.

**Further details on SPS HARQ-ACK applicable for deferral:**

First, one question is how the deferral is configured, i.e. is it applicable for HARQ or any SPS configuration, only for certain SPS configurations or is it limited to e.g. high PHY priority etc.

To have more clarity on this issue the following question is brought forward:

**Question 2.1.1: How is the deferring of SPS HACK configured / the HARQ-ACK of which SPS configurations is subject to potential deferral?**

* **Alt. 1: Joint RRC configuration of the deferral per PUCCH cell group (i.e. any SPS HARQ-ACK in principle is subject to deferral)**
	+ **Supporting companies:** …
* **Alt. 2: RRC configuration of deferral per PUCCH configuration (i.e. can be configured for low and/or high PHY priority PUCCH separately, all SPS configurations with low and/or high PHY HARQ-ACK priority are in principle subject to deferral)**
	+ **Supporting companies: DCM,** …
* **Alt. 3: The deferral is configured per SPS configuration (i.e. part of sps-config, only HARQ-ACK of SPS PDSCH configurations is in principle subject to deferral)**
	+ **Supporting companies:** vivo**, Sony, Nokia/NSB, DCM, Intel, Panasonic, NEC, Sharp**
* **Alt. 4: Other (**please provide your input below)
	+ **Supporting companies:** …
	+ **Indicated in the SPS Activation DCI: Sony**

|  |  |
| --- | --- |
| *Company* | *Comments or Alt. 4 – other options* |
| vivo | Alt.3. Different SPS configurations can be used for different service type, some SPS configurations may have short periodicity so it is difficult to avoid the collision between the corresponding HARQ-ACK feedback and semi-static DL/SSB. Some SPS configurations may have longer periodicity, then the configuration for its HARQ-ACK feedback can avoid the semi-static DL/SSB symbols. Note that Alt.3 can achieve Alt.1 and Alt.2. |
| OPPO | Alt.1 is simple and Alt.3 provides flexibility. So, both Alt.1 and Alt.3 can be further studied. |
| Xiaomi | We prefer alt 3, in which the deferral is configured per SPS configuration. Different SPS configurations can has different period corresponding to different service with different latency requirements. It is suitable to configure the SPS HARQ based on per SPS configuration. Regarding to some HARQ bundling for traffic jitter and TSN cases, multiple SPS configuration can share the same deferral configuration.The granularity of SPS configuration in alt 1 is too large and has no enough flexibility. |
| Sony | Alt.3. or Alt.4, since they provide the most flexibility. Alt.4 got the benefit that it can be changed dynamically. |
| Nokia,NSB | Per SPS config prefered |
| DCM | Alt 2 or Alt 3. From our perspective, we don’t see other motivation to enable deferring for part of SPS configurations with the same priority than possible different HARQ-ACK reporting latency considerations for different SPS configurations. Maybe the question is related with “Question 2.2.2”. Alt 3 can achieve Alt 2 by simultaneously enabling deferring for all activated SPS configurations with the same HARQ-ACK priority. Alt 2 can achieve Alt 3 by separately configuring maximum deferral limitation, e.g. the maximum effective deferral K1 is equal to indicated K1. |
| Samsung | Alt. 1 For alt. 2/alt. 3, it is not clear why deferring is configured per PUCCH/SPS configuration as anyhow it is evident that HARQ-ACK is dropped for all cases. In this sense, alt. 1 is simple and straightforward method.  |
| Intel | Prefer Alt. 3. The reliability (and thus enabled deferring) may be needed only for a subset of services (and thus SPS configurations). |
| CATT | We think Alt. 1 is sufficient and the motivation for additional flexibility is not clear to us. |
| Panasonic | We prefer Alt.3 in which the deferral is configured per SPS configuration. |
| NEC | Alt.3 is preferred for flexibility. |
| Sharp | Alt.3 is preferred. |
| Lenovo, Motorola Mobility | Alt 3 is preferred. A certain SPS configuration of a higher HARQ-ACK priority index may be intended to serve traffics with very tight latency requirement. In this case, HARQ-ACK feedback can be simply dropped, while HARQ-ACK feedback can be deferred for other SPS configurations of the higher HARQ-ACK priority index. Alt3 allows differentiation among SPS configurations of the higher HARQ-ACK priority index. |
| WILUS | Alt. 3. Not necessary to defer HARQ-ACK for all SPS configurations. Deferring HARQ-ACK for a SPS configuration due to TDD collision can be configured by gNB based on service type of the SPS configuration. |
| Spreadtrum | We prefer Alt. 1 and Alt.3, Alt. 1 is simple and can be seen as a special case of Alt.1, while Alt.3 is flexible.  |

Assuming there is a PUCCH dropped for TDD, what are the conditions that the SPS HARQ-ACK of the PUCCH is subject to deferral, would need to be discussed as well. Some companies discussed, that the only a PUCCH is subject to the deferral, if the initial PUCCH resource based on *SPS-PUCCH-AN-List-r16* is not valid (or as one company explained it, if the codebook is only to include SPS HARQ).

To see if this is something that could be a starting point, the following question is brought forward. **If you have another option in mind here, maybe add the alternative below and explain a bit more** in the table below. Please add your company name directly to the list of supporting companies in the questions below.

**Question 2.1.2: What is the condition of SPS HARQ-ACK dropped for TDD to be subject to deferal?**

* **Alt. 1: Deferral only, if the initial resource based on *SPS-PUCCH-AN-List-r16* is not valid**
	+ **FFS on the definition of ‘not valid’ (incl. TDD configuration and semi-static flexible symbol handling)**
	+ **Supporting companies: vivo, Nokia/NSB, DCM, Intel, Panasonic, NEC, Sharp**
* **Alt. 2: …**

|  |  |
| --- | --- |
| *Company* | *Comments or other options/alternatives* |
| vivo | Alt.1. Note that when SPS HARQ-ACK will be further multiplexed with dynamic HARQ-ACK, no collision will be expected based on dynamic scheduling. So only the SPS HARQ-ACK can be considered when determining if a deferral should be performed. |
| OPPO | We should clarify the definition of “available PUCCH resource” firstly, which is always necessary to solve dropped SPS HARQ-ACK issue regardless deferring condition.However deferring condition is not necessary for some definition of “available PUCCH resource”. For example, appropriate K1 is configured for each UL slot for SPS HARQ-ACK feedback. |
| Xiaomi | We are fine with alt 1. |
| Sony | Deferred if the HARQ-ACK (rather than the PUCCH resource) corresponding with the SPS cannot be sent. The SPS HARQ-ACK could be multiplexed into an overlapping PUCCH corresponding to a DG-PDSCH or into a DG-PUSCH. |
| Nokia, NSB | Multiplexing on a different PUCCH resource should not trigger deferral.  |
| DCM | Support Alt 1. Agree with vivo that no collision is expected if SPS HARQ-ACK is multiplexed with dynamic HARQ-ACK. |
| Samsung  | Alt. 2: **Deferral only, if there is no valid PUCCH resource in the initial slot.** * + **FFS on the definition of ‘valid PUCCH resource’ (incl. TDD configuration and semi-static flexible symbol handling)**

As explained in our contribution [23], using the PUCCH resource configured in *PUCCH-ResourceSet* is beneficial for latency of HARQ-ACK in TDD. Because there is only one PUCCH resource in *SPS-PUCCH-AN-List-r16* for a given payload. In TDD scenario, using only the PUCCH resource in *SPS-PUCCH-AN-List-r16* may increase the latency as shown in the figure below.Basic rule to facilitate this method is that UE firstly check whether PUCCH resource related to sps-PUCCH-AN-List-r16 is available or not, then if not satisfied, UE will check other PUCCH resources according to configured PUCCH resource index based on PUCCH-ResourceSet based on SPS HARQ-ACK payload size/index |
| Intel | Support Alt. 1.  |
| CATT | We are not sure what Alt. 1 exactly means.In general, we think whether SPS HARQ-ACK should be delayed 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 to avoid the potential misalignment between gNB and UE in case UE misses DCI. Furthermore, there are following two options* Option 1: The PUCCH resource used for delayed SPS HARQ-ACK only is used to determine the next available PUCCH resource

Option 2: The PUCCH resource used for both initial and all delayed SPS HARQ-ACK is used to determine the next available PUCCH resource |
| Panasonic | We support Alt.1. |
| NEC | We are fine with Alt.1. |
| Sharp | We support Alt.1. |
| Lenovo, Motorola Mobility | Alt 1HARQ-ACK for SPS PDSCH(s) is deferred only if an initial resource based on *SPS-PUCCH-AN-List-r16* or *n1PUCCH-AN* is not valid. |
| WILUS | Not clear on the meaning of “the initial resource based on *SPS-PUCCH-AN-List-r16*”. In R16 URLLC, to carry more than one SPS HARQ-ACK bits, up to 4 PUCCH resources can be provided in *SPS-PUCCH-AN-List-r16* and one PUCCH resource is selected based on SPS HARQ-ACK size. In this proposal, the initial resource can be interpreted as 1) the PUCCH resource based on “non-deferred SPS HARQ-ACK” or 2) the PUCCH resource based on “non-deferred SPS HARQ-ACK and deferred SPS HARQ-ACK.” |
| Spreadtrum | Support Alt.2 proposed by Samsung. |

**Question 2.1.3: What is the definition of ‘not valid’ of Alt. 1 of Question 2.1 (or possibly other alternatives) in term of collision?**

* **Alt. 1: Semi-static DL symbols or SSB**
	+ **Supporting companies: vivo, Sony, Nokia/NSB, DCM (if type 3 HARQ-ACK feedback supported for the issue), Intel, Panasonic, NEC, Sharp, …**
* **Alt. 2: Semi-static DL / SSB and flexible symbols**
	+ **Supporting companies: DCM (if type 3 HARQ-ACK feedback not supported for the issue) …**
* **Alt. 3: …**

|  |  |
| --- | --- |
| *Company* | *Comments or other options/alternatives* |
| vivo | Slightly prefer Alt.1. For Alt.2, we would like to clarify that if the semi-static flexible symbol(s) is/are not overwritten by dynamic SFI/dynamic DCI as flexible/DL, then they are considered as valid; otherwise, the semi-static flexible symbol(s) is/are not valid.  |
| OPPO | The same comment as Question 2.1.2.We should clarify the definition of “available PUCCH resource” firstly rather than definition of “not valid”. Appropriate K1 configuration ensure that PUCCH resource is always valid. |
| Xiaomi  | The same view as vivo and oppo. Flexible symbols in some cases belongs to the available resources and need to be clarified.  |
| Sony | Preference for Alt.1 for case where the flexible symbol is reliably indicated, e.g. by UL Grant.Note: In Rel-16, flexible symbol can be used for PUSCH transmission if that flexible symbol is indicated in the UL Grant of that PUSCH. This was introduced to overcome the reliability issue of the SFI. Hence in some case, the flexible symbol can be reliably used. |
| DCM | It depends on whether type 3 HARQ-ACK feedback is supported for the issue. If Type3 HARQ-ACK feedback is not supported, SPS HARQ-ACK deferring should solve the issue thoroughly, which means possible HARQ-ACK dropping due to collision with semi-static flexible symbol should also be considered. Then our preference is:Alt.1 if Type 3 CB is also supported for ReTx* Alt.2 if Type 3 CB is not supported for ReTx
 |
| Samsung | Alt. 1 |
| Intel | We are supportive of Alt.1 assuming that when flexible symbols are invalidated dynamically, the feedback will not be postponed, but dropped. |
| CATT | Alt. 1.  |
| Panasonic | We prefer Alt.1.  |
| NEC | Alt.1 is preferred.  |
| Sharp | Alt. 1 |
| Lenovo, Motorola Mobility | Alt 1 is preferred.For Alt 2, need a note, “It is not expected that dynamic SFI or dynamic DCI indicates semi-static flexible symbols overlapping with a PUCCH resource of HARQ-ACK feedback as DL or flexible symbols”.  |
| WILUS | Alt. 1. Semi-static flexible symbol can be used for PUCCH transmission at least if dynamic SFI is monitored and indicates UL symbols.  |
| Spreadtrum | Alt.1 is preferred. |

**Question 2.1.4: Do you think there are other things that need to be considered here when defining the applicable PUCCH / SPS HARQ-ACK for deferral (in the initial phase or overall)? If so, please provide your input below.**

|  |  |
| --- | --- |
| *Company* | *Comments*  |
| OPPO | Complexity, load balance, system efficiency and spec workload should be consideredSemi-static PUCCH/K1 determination is easier to implement and avoid misunderstanding due to dynamic signalling missing, e.g. dynamic SFI missingPUCCH resource/K1 configured by gNB directly, e.g. Mapping between SPS PDSCH and UL slot is determined semi-statically, can balance PUCCH payload in limited slot/subslot, improve multiplexing efficiency and avoid workload in spec, e.g. deferring condition, definition of available resource, delay budget and so on. |
| DCM | Load balancing issue may need to be addressed considering most HARQ-ACK will be deferred to the first UL slot. Inter-UE collision and/or beam misalignment issue in FR2 is also possible for SPS HARQ-ACK deferring since UE determines PUCCH transmission timing by itself. One possible solution is that gNB can indicate permitted T/F resources for SPS HARQ-ACK deferring, e.g. only on certain slots/sub-slots according to gNB indication/configuration. |
| Samsung | Maximize re-use of LTE and Rel-15 designs when a PUCCH repetition is deferred. |
| NEC | In a configuration with both dropped and deferred SPS HARQ-ACK bits for a configured K1 set, UE may not have sent an acknowledgement even for the deferred ‘SPS HARQ-ACK’, e.g. due to misdetection. It may be better to also send the expired SPS HARQ-ACK as ‘NACK’, or else it may cause misalignment between UE and gNB. |
|  |  |

**Further details on conditions / deferral in terms of slot/sub-slot offset for deferal:**

As also brought up today, there could be restrictions on the deferral here and there had been restrictions suggested by several companies including at least having a maximum deferral defined (or given by the max. configured k1 value), the effective overall ‘k1’ value of the deferred HARQ-ACK to be restricted to an entry of the configured K1 set).

To not conflict with what k1 here means, let’s use the following definition for our discussions here:

* ***k1*** is the slot/sub-slot offset for the SPS HARQ as given by the SPS activation DCI (based on the current understanding what ‘k1’ is)
* ***k1def*** is the slot/sub-slot offset of the deferral (i.e. slot offset between the initial, dropped PUCCH / HARQ and the slot of the deferred PUCCH / HARQ transmission)
* ***k1eff*** is the effective PDSCH to HARQ-ACK feedback offset (in slots/sub-slots) for the deferred HARQ, i.e. ***k1eff=k1+ k1def***

Now having this is in place, let’s see what different things need to be considered in terms of limitation on *k1def* and *k1eff*.

* Principle granularity of *k1def* / steps for deferral: Is the granularity 1 or given by the SPS periodicity?
	+ ***Moderator comment:*** If it is given by the periodicity P, how to handle the case of two SPS HARQ-ACK on a PUCCH with different periodicity *P* configured? Proponents of P should please provide their suggested handling below.
* Should the deferral *k1def* overall be limited to a certain number of slots (e.g. *k1def ≤ k1def,max*)? Should the maximum deferral be e.g. RRC configured?
	+ Target here would be to not defer too long…
* Or should instead the maximum effective PDSCH-HARQ offset be limited (e.g. *k1eff* *≤ k1eff,max*) – where e.g. *k1eff,max* is given by the largest k1 value in the K1 set (or alternatively RRC configured)?
	+ ***Moderator comment:*** How to handle the case of SPS HARQ-ACK of two SPS configurations on a PUCCH with different *k1* value activated? **Proponents of this operation should please provide their suggested handling here** (e.g. is only one of them deferred for which the condition still applies – or then both not deferred as for part of the SPS HARQ-ACK the condition is violated)=
* Should *k1eff* to be limited to an existing k1 entry / value of the K1 set(s)?
	+ The argument seems to be mainly coming from easier handling of type 1 CB operation (see the input on multiplexing by different companies in Sec. 2)
	+ ***Moderator comment:*** Same issue as mentioned above.How to handle the case of SPS HARQ-ACK of two SPS configurations on a PUCCH with different *k1* value activated? Would only (a) only a subset of SPS HARQ-ACK be deferred with a certain slot offset (due to the limitation of the K1 set) or (b) the SPS HARQ-ACK be deferred to one slot / sub-slot satisfying conditions for all SPS HARQ applicable for deferral (potentially leading to not deferring any of the bits)? **Proponents of this condition should please provide their suggested handling here**

Looking first at some proposals (from companies, it seems the following options on the limitations have been mentioned:

**Question 2.2.1: What is the slot/subslot granularity of the SPS HARQ-ACK deferral?**

* **Alt. 1: 1 slot / sub-slot**
	+ **Supporting companies: vivo, Sony, Nokia/NSB, DCM, Panasonic, NEC, Sharp, …**
* **Alt. 2: P slots / sub-slots**
	+ **P is determined by SPS PDSCH periodicity**
		- **Handling of different periodicities for different SPS configurations needed, proponents to provide details below**
	+ **Supporting companies: …**
* **Alt. 3: Other**
	+ **Supporting companies: …**
	+ **Number of OFDM symbols: Sony**

|  |  |
| --- | --- |
| *Company* | *Comments or other options/alternatives* |
| vivo | Alt.1. We think the deferral can be determined per slot/sub-slot, subject to the potential requirement for ***k1eff***. |
| OPPO | Alt.1. Keep the same granularity as K1. |
| Xiaomi | We prefer alt1. |
| Sony | Alt.1 or Alt.4. Alt.1 granularity should follow the K1 granularity of the SPS.Alt.4 provides an absolute granularity, i.e. number of symbols and so it can be independent of K1. |
| DCM | Support Alt 1. |
| Samsung | Alt. 1 |
| Intel | We think the granularity aspect is not urgent to decide, and it may be an automatic decision as part of some other discussions. For example, if a UE is provided with a dedicated PUCCH resource and k1 that can be used instead of the original PUCCH, then the granularity does not matter. |
| CATT | Alt. 1 |
| Panasonic | We prefer Alt.1. |
| NEC | Support Alt.1. |
| Sharp | Alt. 1 |
| Lenovo, Motorola Mobility | Alt 1 |
| WILUS | Alt 1 provides the earliest available slot for SPS HARQ-ACK so that it may be the best option in terms of HARQ-ACK latency. However, when considering TDD configuration, the SPS HARQ-ACK bits are deferred to the first UL slot right after consecutive DL slots. load balance of SPS HARQ-ACK bits should be discussed jointly.  |
| Spreadtrum | We prefer Alt.1. |

**Question 2.2.2: Limitation on the maximum deferral in time domain**

* **Alt. 1: The limitation is given in number of slots for the deferral itself by *k1def ≤ k1def,max***
	+ **Definition of is *k1def,max* FFS**
	+ **Supporting companies: Sony, Nokia/NSB, Sharp …**
* **Alt. 2: The deferral limitation is given in the total PDSCH to HARQ-ACK delay/offset, i.e. *k1eff=k1+k1def*** ***≤ k1def,max***
	+ **Definition of *k1def,max* is FFS (e.g. max. k1 value of the configured K1 set)**
	+ **Handling of different initial k1 for different SPS configurations needed, proponents to provide details below**
	+ **Supporting companies: vivo, DCM, Panasonic, NEC, …**
* **Alt. 3: Other**
	+ **Supporting companies: …**

|  |  |
| --- | --- |
| *Company* | *Comments or other options/alternatives* |
| vivo | Based on Alt.2, the HARQ-ACK for each SPS configuration in the overall deferred SPS HARQ-ACK will be judged against *k1eff,max*, and only the SPS HARQ-ACK for which the condition is still met can be deferred, otherwise the SPS HARQ-ACK should be dropped without further deferral. |
| OPPO | Alt2. *k1def,max* is max. k1 value of the configured K1 set for DCI format 1\_1/1\_2. |
| Xiaomi | We prefer alt 1.Firstly, alt 1 is simple and common for all SPS configurations. Besides, in alt 2, different SPS configurations has different initial k1 value, so the final k1def,max is difficult to decided. For some SPS configuration, if the K1 value is close to k1def,max, SPS HARQ-ACK only can be deferred in few slots and it may lead to no available resources for choosing. |
| Sony | Alt.1. There isn’t really that much of a difference between Alt.2 and Alt.1 but in Alt.1 at least UE need only to care about this *k1def* only when it has dropped a HARQ-ACK and apply the value of *k1def* directly. Also, in addition to *k1def*, shouldn’t there be at least some processing time between the last dropped PUCCH and the 1st available PUCCH so that UE can process the updated number of HARQ-ACK into the 1st available PUCCH? |
| Nokia, NSB | We think that having a limit per SPS HARQ bit may become a bit too complicated to operate.  |
| DCM | Prefer Alt 2 since HARQ-ACK reporting latency is the motivation to limit maximum deferral offset.Separate deferral handling for bits corresponding to different SPS configurations with different initial k1 in one HARQ-ACK CB is possible. For example, HARQ-ACK bits which can’t fulfil the deferral limitation will be dropped and HARQ-ACK bits fulfilling deferral limitation can be deferred.  |
| Samsung | Alt. 1 |
| Intel | Similar to Q 2.2.1, this question seems goes too deep into one kind of solution, and thus may be premature to be discussed before a more general decision on how substitute PUCCH resource can be determined/provided. |
| CATT | We don’t think the limitation is needed since we support the next proposal. |
| Panasonic | If limitation is supported, we prefer Alt.2. |
| NEC | Support Alt.2. We share same view with vivo that the limitation of the maximum delay for SPS HARQ-ACK feedback should be the total PDSCH to HARQ-ACK delay ***k1eff ≤ k1def,max***. |
| Sharp | We prefer Alt. 1, which is a simple and direct way.  |
| Lenovo, Motorola Mobility | Alt 1 |
| WILUS | We prefer Alt. 1 if limitation is supported. |
| Spreadtrum | Support Alt.1.  |

**Question 2.2.3: Should the effective total/effective PDSCH to HARQ-ACK offset *k1eff* be limited to an existing k1 value in the applicable K1 set(s)?**

* **Companies suggesting ‘Support’, please provide you handling of different k1 values activated for more than one SPS configuration with HARQ-ACK on the deferred PUCCH in below’s table (see moderator comments above)**
* **Companies supporting (Yes): vivo, …**
* **Companies not supporting (No): Sony, Nokia/NSB, DCM, NEC, Sharp …**

|  |  |
| --- | --- |
| *Company* | *Supporting companies: how to handle different k1’s in the SPS activation DCI**Not supporting companies: why is this restriction not needed?* |
| vivo | The comment can refer to that for Question 2.2.2. Only the part of SPS HARQ-ACK for which the condition regarding *k1eff,max* is still met can be deferred. |
| OPPO | *k1def,max* is max. k1 value of the configured K1 set for DCI format 1\_1/1\_2. |
| Xiaomi | We have no strong concern |
| Sony | Not support.We do not see any need to restrict this. Why can’t the gNB just provide a number to the UE? |
| Nokia, NSB | We see no need fur such restriction. For Type 2 CB there is no reason at all, and for Type 1 CB the bits could be amended (as discussed by several companies). So the only limitation may be the longest deferral (previous question).  |
| DCM | We don’t prefer to have such limitation from the perspective of possible OOO issue. As in the example, assuming K1 set = {1,3,5,7,…}, deferred SPS HARQ-ACK for SPS PDSCH #1 is later than the later SPS PDSCH #2. |
| Samsung | No – up to the gNB. Can revisit this issue subject to minimum specification impact.  |
| Intel | k1 for deferral should be controlled by gNB, thus no explicit total offset limitation is required. |
| CATT | Support to minimize the specification impact to HARQ-ACK CB construction.  |
| NEC | Not support.We understand the intention is to minimize the standardization effort. With the condition, no enhancements on Type-1 CB for delayed SPS HARQ-ACK are needed, but it seems too restrictive. For example, as shown in the figure below, the SPS HARQ-ACK for SPS configuration #1 cannot be transmitted on the deferred PUCCH resource since its ***k1eff =4*** is not in the K1 set{2,3,5,6} configured for the UE. Regarding the Type-1 HARQ-ACK CB construction, a simple method to append the delayed SPS HARQ-ACK to the end of the Type-1 CB for non-delayed HARQ-ACK can be considered.  |
| Sharp | No – up to the gNB. |
| Lenovo, Motorola Mobility | Not support. We don’t think such a restriction is necessary (i.e. the max delay for deferred HARQ-ACK feedback can be larger than normal (i.e. non-deferred) HARQ-ACK feedback timing configured in K1 set). |
| WILUS | Not support. OoO issue may occur as described by DCM. Also, for type-2 CB, no benefits with such a limitation. |
| Spreadtrum | Not support. The limit is too strict and the opportunity for delay SPS to generate a codebook may be very low. |

**Question 2.2.4: Do you see that we need to handle other limitations in terms of *k1/k1def/k1eff*? If so, please provide your input below.**

|  |  |
| --- | --- |
| *Company* | *Additional proposed conditions / limitations in terms of k1/k1def/k1eff* |
| Sony | Shouldn’t there be some processing time between the last dropped PUCCH and the 1st available PUCCH? Surely the UE would need time to update the number of HARQ-ACK after the last dropped PUCCH before it can be transmitted into the 1st available PUCCH. |
|  |  |
|  |  |
|  |  |
|  |  |

**Further details on potential multiplexing of deferred SPS HARQ-ACK:**

As discussed above, the moderator has the feeling that the support of multiplexing should be discussed (and potentially) agreed early, as this may have an effect of the discussion on the definition of the next available PUCCH and which PUCCH resource sets are to be selected. Just as an example, if multiplexing of deferred SPS HARQ-ACK on a ‘scheduled’ PUCCH is possible – could this be done even though the ‘scheduled’ PUCCH resource would not be overlapping with a candidate resource for SPS HARQ-ACK deferral (or not)? Just to have an idea early, how many different cases need to be considered (with potentially different handling).

**Question 2.3.1: For multiplexing of defered SPS HARQ-ACK with other UCI, the following alternatives can be considered:**

* **Alt. 1: Multiplexing of deferred SPS HARQ-ACK with any other UCI is not supported**
	+ **Supporting companies:** …
* **Alt. 2: Multiplexing of deferred SPS HARQ-ACK with non-deferred SPS HARQ-ACK is supported and/or**
	+ **Supporting companies: vivo, Sony, Nokia/NSB, DCM, Panasonic, NEC, Sharp,** …
* **Alt. 3: Multiplexing of deferred SPS HARQ-ACK with non SPS HARQ-ACK is supported and/or**
	+ **Supporting companies: vivo, Sony, Nokia/NSB, DCM, Panasonic, NEC, Sharp,** …
* **Alt. 4: Multiplexing of deferred SPS HARQ-ACK with SR/LLR is supported and/or**
	+ **Supporting companies: vivo, Nokia/NSB, DCM, Panasonic, Sharp** …
* **Alt. 5: Multiplexing of deferred SPS HARQ-ACK with CSI on PUCCH is supported and/or**
	+ **Supporting companies: vivo, Nokia/NSB, DCM, Panasonic, Sharp** …
* **Alt. 6: Other (**please provide your input below)
	+ **Supporting companies:** …
	+ **A triggered PUCCH resource: Sony**

|  |  |
| --- | --- |
| *Company* | *Comments or Alt. 5 – other options* |
| vivo | We support Alt.2, Alt.3, Alt.4, Alt.5. We think for deferred SPS HARQ-ACK multiplexing with other UCI, legacy mechanisms in Rel-15/16 should be reused as much as possible. |
| OPPO | Alt5. If deferred SPS HARQ-ACK collides with PUCCH with other UCIs, follow multiplexing procedure without HARQ-ACK codebook restriction for deferred SPS HARQ-ACK.Intention of Alt2-4 category is not clear for us. |
| Xiaomi | We support alt 2, alt 3, alt 4.  |
| Sony | At least support Alt. 2 and Alt. 3 to provide sufficient opportunity & reliability (since they are scheduled for HARQ-ACK) to transmit the dropped PUCCH. We can consider Alt.6 where a PUCCH resource is triggered when *N* number of SPS HARQ-ACK are dropped to reduce latency if the 1st available PUCCH is too far away. |
| DCM | Alt 2 , Alt 3, Alt 4 and Alt 5.In our opinion, if UE reports non-deferred HARQ-ACK (including dynamic HARQ-ACK and/or SPS HARQ-ACK) in one slot, and the slot is to be determined as deferred reporting slot for deferred SPS HARQ-ACK with the same priority, one HARQ-ACK CB is generated to multiplex non-deferred HARQ-ACK and deferred SPS HARQ-ACK. We understand it as R15/R16 HARQ-ACK multiplexing principle.For multiplexing with other UCIs, it can be considered after the HARQ-ACK PUCCH is determined and R16 UCI multiplexing scheme can be reused. |
| Samsung | Alt. 6 – deferred SPS HARQ-ACK is treated as “regular”/non-deferred HARQ-ACK and Rel-16 multiplexing rules remain applicable. Otherwise, no clear benefit bothering with deferring as, in TDD, multiplexing with other UCI will be practically always needed. |
| Intel | Agree with Samsung, we view the deferral / substitution process as just a mechanism to change the possible occasions for HARQ-ACK multiplexing comparing to R15-16. But the capability of multiplexing should not change, thus support at least what can be achieved in R15-16. |
| CATT | We support Alt.2, Alt.3, Alt.4, Alt.5. |
| Panasonic | We support Alt.2, 3, 4, and 5. Multiplexing of deferred SPS HARQ-ACK with any other UCI could be considered based on Rel.15/16 specification. |
| NEC | At least support Alt.2 and Alt.3 that multiplexing for deferred SPS HARQ-ACK and non-deferred SPS HARQ-ACK and/or HARQ-ACK for DG PDSCH in a PUCCH resource is allowed in Rel-17. FFS Alt.4 and Alt.5. |
| Sharp | We are OK with Alt.2, Alt.3, Alt.4, Alt.5. |
| Lenovo, Motorola Mobility | Alt 2, 3, 4, and 5. ‘LLR’ in Alt4 seems to be a typo. Suggest changing to ‘LRR (link recovery request)’  |
| WILUS | Agree with Samsung and Intel. We think R17 deferring of SPS HARQ-ACK is just a rule to determine a PUCCH resource for SPS HARQ-ACK. Special handling on UCI multiplexing for deferred SPS HARQ-ACK is not preferred. R15/16 UCI multiplexing rules can be applied. |
| Spreadtrum | Support Alt.2, Alt.3, Alt.4, Alt.5. |

# Retransmission of cancelled HARQ

In this section, the company positions on the support of retransmission of cancelled HARQ-ACK are summarized.

Overall, the following input on the **support of re-transmission of canceled HARQ-ACK** in Rel-17 was given:

* **Support:** ZTE [1], OPPO [2], vivo [7]
	+ For LP HARQ-ACK: ZTE [1] (LP prioritized, same principle could be applied to HP HARQ)
	+ For HP HARQ-ACK:
	+ For LP & HP HARQ-ACK: vivo [7] (unified solution), Mediatek [8] (not optimized for HP HARQ) Sony [12] (mechanism also applicable to HP HARQ), APT [17]
* **No support:** Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], China Telecom [14] (‘study with low priority)
* **Cons:** Not essential for LP HARQ (e.g. in [1] Huawei / HiSi [3], BUPT [3] and China Southern Power Grid), can be avoided for HP HARQ by gNB implementation (e.g. in [1] Huawei / HiSi [3], BUPT [3] and China Southern Power Grid)

Suggested **methods to support re-transmission of canceled HARQ-ACK**:

* **Alt. 1 - Support of Type 2 CB Enhancements:** 2x Yes – 1x No
	+ **Yes:** vivo [7] (but Type 3 with higher priority), APT [17]
	+ **No:** Nokia [10]
	+ **Cons against Type 2 CB usage:**
	+ **Details:**
		- PHY priority enhancement - two PDSCH groups per PHY priority/PUCCH configuration: vivo [7], APT [17]
* **Alt. 2 - Support of Type 3 CB Enhancements:** 19x Yes – 1x No
	+ **Yes:** Ericsson [4], CAICT [5], CATT [6], vivo [7], Intel [9], Nokia [10], Sony [12], LGE [13], TCL [15], NEC [16], Moto/Len [18], ETRI [21], Xiaomi [22], Interdigital [24], Apple [25], Qualcomm [26] , Sharp [27], DOCOMO [28], WILUS [29]
	+ **No:** Samsung [23]? (large Type 3 CB overhead, otherwise new codebook)
	+ **Const against Type 3 usage:** large overhead (e.g. ZTE [1]), mix of HP & LP HARQ bits (e.g. ZTE [1]), need for UE to reconstruct codebook (e.g. ZTE [1]), any payload size optimization would basically mean introducing a new codebook (Samsung [23])
	+ **Suggested Type 3 CB enhancements:**
		- PHY priority indication in the triggering DCI of the PUCCH carrying the Type 3 CB: Ericsson [4], Nokia [10], APT [17], Apple [25], Sharp [27], WILUS [29]
		- Only consider activated CCs: Ericsson [4]
		- Only subset of configured CCs: Nokia [10], ETRI [15], Xiaomi [22], Apple [25]
		- Only dropped HARQ-ACK: CAICT [5], TCL [15], Panasonic [19], Interdigital [24] (based on a flag)
		- DCI format support (i.e. DCI format 1\_2): CAICT [5], Nokia [10], WILUS [29]
		- Only SPS HARQ processes: Intel [9], TCL [15], NEC [16], Panasonic [19], ETRI [21], , Xiaomi [22] (including indicated subset)
			* Including a subset of SPS configurations defined by RRC or dynamic indication: NEC [16]
		- Configure if all HARQ processes or only (certain) SPS HARQ processes are included: CATT [6], LGE [13] (RNTI of the triggering DCI to distinguish), Apple [25], WILUS [29]
		- Allow the dynamic triggering to indicate a sub-set of HARQ processes / cells: vivo [7], Nokia [10], LGE [13], Xiaomi [22], WILUS [29]
		- Support grouping of HARQ processes: Intel [9]
		- Consider autonomous (without DCI) Type 3 CB triggering when *NDrop* SPS HARQ-ACKs are dropped: Sony [12]
		- Consider handling of retransmissions of cancelled HARQ-ACK with one L1 priority and/or codebook type in another HARQ-ACK codebook of different L1 priority and/or different codebook type: Sony [12]
		- Autonomous Type 3 CB transmission on CG-PUSCH resources: Moto/Len [18]
		- Separate Type 3 CB configuration for low and high PHY priority: Apple [25]
		- N bits in the Type 3 HARQ codebook, where the bits of SPS HARQ-IDs within a time window are to be mapped: Qualcomm [26]
		- HARQ processes limited to a given time window: Qualcomm [26], DOCOMO [28]
		- Separate Type 3 CB construction for HP and LP: DOCOMO [28] – either NACK for the different priority or variable size (possible ambiguity)
		- Inclusion of HARQ-ACK of SPS release DCI: WILUS [29]
* **Alt. 3 - UL grant scheduling PUSCH to carry dropped HARQ:** 3x Yes – 1x No
	+ Yes: ZTE [1], Nokia [10] (UL grant re-tx triggering, semi-static configuration for CG PUSCH), Samsung [23] (without UL-SCH)
	+ No: vivo [7]
* **Alt. 4 - DCI scheduling new PUCCH / PUSCH resource for LP HARQ re-transmission:** 2x Yes – 1x No
	+ **Yes:** ZTE [1], OPPO [2]
	+ **No:** vivo [7]
	+ Triggering possible as soon as the conflict is determined: ZTE [1]

## 3.1 First round of email discussions

*Moderator comments:*

The following support / not support for the 4 different techniques have been indicated by the different companies:

* **Alt. 1 - Support of Type 2 CB Enhancements:** 1x Yes – 1x No
* **Alt. 2 - Support of Type 3 CB Enhancements:** 19x Yes – 1x No
* **Alt. 3 - UL grant scheduling PUSCH to carry dropped HARQ:** 3x Yes – 1x No
* **Alt. 4 - DCI scheduling new PUCCH / PUSCH resource for LP HARQ re-transmission:** 2x Yes – 1x No

The moderator would like to in addition note the following:

* There (at least for the moment) there seems to be **little support or interest in Alt. 1, 3 & 4 compared to Type 3 CB operation enhancements of Alt. 3**. It is therefore proposed, to **focus the related discussions (at least) during the first week on Type 3 CB enhancements**.
* It seems to be not really helping to agree to support some Type 3 codebook enhancements (without knowing which). Therefore, it is suggested to **discuss and potentially agree different Type 3 CB enhancements directly (and if needed one by one throughout the WI phase)**.
* When looking at the **details of the proposed Type 3 CB enhancements**, at least the following can be noted (without discussing all of them here, please check the summary in Sec. 3):
	+ Several companies indicated the need to have the PHY priority index of the PUCCH associated with the triggered Type 3 CB defined (using the Rel-16 PHY priority indication). It seems that at least such enhancement is needed to be compatible with the Rel-16 PHY priority framework. It is therefore suggested to try to agree on this. This does not preclude any additional enhancements with respect to PHY priority operation.
	+ Several companies seem to suggest to support the triggering using DCI format 1\_2 in Rel-17. The operation should be clear and just some details on the fixed bits in DCI format 1\_2 (as done in 1\_1) may be needed. Therefore, the moderator thinks the suggestion should be complete and therefore RAN1 could be in a position to agree to such related proposal (related proposal provided)
	+ There have been plenty of different proposals on how to reduce the Type 3 CB size for the purpose of cancelled HARQ (for SPS and/or DG PDSCH) or specifically for retransmission of dropped SPS HARQ-ACK. The moderator feels that discussing these in the first round of email discussions may not be bringing the group too much further. At this point otherwise, there could maybe a generic agreement to have support for a Type 3 CB not including all HARQ IDs of all configured CCs (i.e. smaller codebook size compared to Rel-16).

Based on the above the following is proposed:

**FL Proposal 3.2: The indicated PHY priority index in the DCI triggering the Type 3 HARQ-ACK codebook defines the PHY priority index of the PUCCH associated with the triggered Type 3 HARQ-ACK codebook. If a priority index is not provided to a UE in the triggering DCI, the priority index is 0.**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 3.2  | Vivo, Sony, Nokia/NSB, DCM, Apple, InterDigital, Intel, CATT, Panasonic, NEC, Sharp, WILUS, Spreadtrum |
| Do not support PHY priority handling for Type 3 CB in Rel-17 | MediaTek,, Samsung, Lenovo/Motorola Mobility  |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | We support reusing existing Type 3 HARQ-ACK codebook. If it is not suitable for URLLC operation, we support adopting Alt. 3 “UL grant scheduling PUSCH to carry dropped HARQ”. |
| OPPO | Retransmission HARQ-ACK includes HARQ-ACKs for eMBB and URLLC. However, Type 3 HARQ-ACK codebook payload is too large to satisfy ultra-reliability requirement for URLLC in some cases. Therefore, payload reduction is the premise of that Type 3 HARQ-ACK codebook is applied for URLLC. If Type3 HARQ-ACK codebook payload cannot be reduced, we support adopting Alt 4.The intention and benefit of PHY priority indication is not clear for us. At least, PHY priority indication can not reduce Type 3 HARQ-ACK codebook payload. |
| Xiaomi | We have no strong concern |
| Samsung | Type-3 HARQ-ACK codebook is irrelevant for the objective of retransmission of a dropped HARQ-ACK codebook. All needed is a trigger and a resource for the UE to retransmit.Type-3 codebook is optional and a UE/gNB cannot be expected to support, even if the UE/gNB support NR-U (no need in general as Type-3 is always inferior to Type-2 which is mandatory). Support of Type-3 HARQ-ACK codebook (and of other NR-U features) in Rel-17 IIoT/URLLC is out of scope. |
| Apple | Feedback overhead with Type 3 CB needs to be addressed so it is more suitable for URLLC |
| Intel | In general we support what is written in the proposal, but agree with OPPO that the main aspect of using Type 3 CB for re-transmission of HARQ-ACK is its payload reduction. |
| Lenovo, Motorola Mobility | Rel-16 Type-3 HARQ-ACK codebook can be reused, whenever possible/applicable. |

**FL Proposal 3.3: Support triggering of Type 3 HARQ-ACK codebook reporting using DCI format 1\_2 in Rel-17.**

* **Further details are FFS.**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 3.3  | Vivo, Nokia/NSB, DCM, InterDigital, Intel, CATT, Panasonic, NEC, WILUS, Spreadtrum |
| Do not support | Samsung, Lenovo/Motorola Mobility |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | We support reusing existing Type 3 HARQ-ACK codebook with DCI format 1\_2. However, if it is not suitable for URLLC operation, we support adopting Alt. 3 “UL grant scheduling PUSCH to carry dropped HARQ”. |
| OPPO | The intention to support DCI format 1\_2 triggering Type 3 HARQ-ACK codebook is not clear.If the intention is to make triggering DCI ultra-reliable for URLLC case, then Type 3 HARQ-ACK codebook payload reduction is the premise of that Type 3 HARQ-ACK codebook is applied for URLLC. If Type3 HARQ-ACK codebook payload cannot be reduced, we support adopting Alt 4. |
| Samsung | Type-3 HARQ-ACK codebook is not relevant for Rel-17 URLLC/IIoT objectives.The proposal is out of scope and precluded by RANP conclusions. |
| Apple | We can first have the design for DCI format 1\_1, then possibility of extending it to DCI format 1\_2 can be explored. |
| InterDigital | We support extending the support of Type-3 HARQ codebook to DCI format 1\_2. |
| Lenovo, Motorola Mobility | Rel-16 Type-3 HARQ-ACK codebook can be reused, whenever possible/applicable. |

There was a trial in the GTW session today to agree to on some codebook size reduction today, as at least from the input documents there had been several proposals to reduce the size, e.g. for SPS HARQ only, smaller number of carriers / HARQ-IDs, only HARQ-IDs of dropped HARQ-ACK etc, HARQ-IDs within some window, etc.. But it seemed that several companies had been of the opinion that the current Type 3 CB definition (i.e. all HARQ IDs of all configured CCs) seems to be sufficient.

Therefore, let’s first try to get an idea of how many companies would support in general, the following proposal is brought forward:

**FL Proposal 3.1: Support some type of Type 3 HARQ-ACK codebook size reduction in Rel-17.**

* **Possible ways / options to reduce the size are FFS.**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 3.1  | Vivo, OPPO, Xiaomi, Sony, Nokia/NSB, DCM, Apple, InterDigital, Intel, Panasonic, NEC, WILUS, Spreadtrum |
| Do not support | MediaTek, Samsung ,  |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | We support reusing existing Type 3 HARQ-ACK codebook. If it is not suitable for URLLC operation, we support adopting Alt. 3 “UL grant scheduling PUSCH to carry dropped HARQ”. |
| OPPO | Type 3 HARQ-ACK codebook can be triggered per carrier to avoid redundant HARQ-ACK information from all carriers.For SPS HARQ-ACK only, only effective HARQ process ID for SPS configuration can be included in Type 3 HARQ-ACK codebook. |
| Samsung | No need for the proposal in Rel-17 URLLC/IIoT.The proposal is also out of scope. |
| Apple | We support Type 3 enhancement, whether NDI, CBG based feedback are configured for a Type 3 codebook should be separately configured for high priority and low priority triggering, targeting URLLC and eMBB applications separately. |
| InterDigital | We support enhancing the HARQ CB type 3 to transmit only the dropped HARQ-ACK codebook instead of all configured HARQ processes. No need to indicate a set of HARQ processes, a flag that will trigger the retransmission of dropped HARQ codebook. |
| CATT | The current proposal seems to be too general. We would prefer to discuss the detailed proposals. |
| Panasonic | In Rel.16, Type 3 codebook contains HARQ-ACK bits of all HARQ processes regardless of priority in the triggering DCI. Therefore, the codebook size could large. Instead of reporting HARQ-ACK for all configured HARQ processes, only transmitting SPS HARQ processes or dropped HARQ processes can be considered. |
| WILUS | We support type-3 CB size reduction by including some of HARQ processes instead of all HARQ processes. The HARQ processes to be included can be indicated in a triggering DCI format or configured by higher layer based on output of Q3.1. |

If a smaller codebook size (however the codebook is constructed) would be supported, but what seems to be common to all seem to be the need to be able to differentiate for the UE if the Rel-16 codebook (i.e. all PDSCH HARQ-IDs of all configured CCs) or a smaller (to be still discussed) sub-Type 3 CB is to be triggered. Therefore, it is suggested first to discuss how to indicate to the UE the different operation here (and trying to get an idea on how many different ‘sub-Type 3’ CB could be triggered by the gNB).

The options mentioned by different companies include:

* Alt. 1: By RRC configuration (semi-static): either the Rel-16 Type 3 CB or a single ‘new’ Type 3 CB of smaller size can be triggered based on semi-static configuration
* Alt. 2: Dynamic indicating using different RNTI (e.g. C-RNTI and CS-RNTI): either triggering Type 3 CB or ‘SPS HARQ re-transmission’ specific Type 3 CB operation
	+ *Moderator comment:* it should be noted here, that the Type 3 CB triggering without scheduling PDSCH is currently limited to the C-RNTI & MCS-C-RNTI (to not conflict with indication of SPS activation / release). See details in Sec. 9.1.4 of 38.213. This may limit exploring this option a bit.
* Alt. 3: Dynamic indication in the DCI – e.g. using some unused bits from the DCI triggering the Type 3 codebook (at least without scheduling a PDSCH of Sec. 9.1.4 of 38.213)
	+ Depending on the number of bits N, 2^N different Type 3 CBs could be triggered.
	+ This could allow to support triggering specifically of one or more different SPS HARQ Type 3 CBs (FFS details, to prevent SPS HARQ-ACK dropping for TDD) as well as supporting one or more different Type 3 CBs for re-transmission of canceled HARQ (for SPS PDSCH and/or DG PDSCH, FFS details on the codebook definition)

**Question 3.1: If smaller Type 3 CB size is supported, how to indicate the triggering of (at least one) ‘smaller’ Rel-17 Type 3 CB to distinguish from the full Rel-16 Type 3 CB:**

* **Alt. 1: by RRC configuration (either Rel-16 or the new codebook can be triggered)**
	+ **Supporting companies:** Sony, DCM, …
* **Alt. 2: Using different RNTI (e.g. C-RNTI & CS-RNTI) – e.g. Rel-16 Type 3 CB and ‘SPS HARQ’ specific codebook**
	+ **Supporting companies:** NEC…
* **Alt. 3: Dynamic indication in the triggering DCI using *N* unsed bits (enabling dynamic indication of up to 2^N different Type 3 CBs)**
	+ **Supporting companies:** vivo, Sony, Nokia/NSB, DCM, Intel, NEC
* **Alt. 4: Other (**please provide your input below)
	+ **Supporting companies:** …

|  |  |
| --- | --- |
| *Company* | *Comments or Alt. 4 – other options* |
| vivo | We prefer Alt.3. Alt.3 has more flexibility in triggering a part of HARQ-ACK information as required and can be used to accommodate to different cases. Meanwhile, no extra overhead is introduced by reusing unused bits in the triggering DCI.  |
| OPPO | Alt 1 and Alt2 are preferred. For CA, Type3 CB size reduction is configured by RRC per carrier to optimize Type 3 HARQ-ACK codebook.For a given carrier, Type 3 codebook payload can be further reduced according to available HARQ-ID for SPS PDSCH.  |
| Xiaomi | We prefer alt 1, each SPS configuration has a period and corresponding SPS HARQ-ACK dropping or deferring is happened in a certain period or within a certain time window, so indicate the triggering of (at least one) ‘smaller’ Rel-17 Type 3 CB by RRC configuration is acceptable.If there is N bits that can be reused without increasing the DCI overhead and changing the DCI format, alt 3 can also be considered. |
| Sony | Alt.1 or Alt.3. |
| Nokia/NSB | Alt. 3 is the most flexible allowing to consider more than one case. Alt. 2 not working (see moderator comments) and Alt. 1 to inflexible.  |
| DCM | Alt 1 or Alt 3.Alt 3 can achieve more flexibility with DCI impact. Alt 1 is simpler without any DCI impact. Moreover, if DCI 1\_2 is enhanced to support type 3 HARQ-ACK feedback triggering, gNB can separately configure “smaller” or “normal” Type 3 HARQ-ACK CB size requested by the two DCI formats. It can also be as flexible as Alt 3. |
| Samsung | No need to discuss question 3.1 |
| InterDigital  | We support dynamic indication to either request the Rel-16 HARQ CB type 3 or enhanced HARQ CB type 3. We think only one bit is needed. |
| Intel | Alt. 3 is preferred. One example where semi-static CB reduction does not work is using it for a general HARQ ReTX including dynamic PDSCH, and for SPS only, where it will not be possible to customize CB e.g. for SPS only HARQ-ACK bits.Note, that it may not be accurate to say “unused”, since a new field may be introduced for this. |
| CATT | The details can be discussed later. |
| NEC | Alt.2 is slightly preferred. It is natural to use DCI scrambled with CS-RNTI to trigger re-transmission for SPS HARQ-ACK only. Not sure if there is a use case that a UE needs to be configured more than 2 kinds of Type-3 CB simultaneously, if so, we are also fine to discuss the Alt.3 further. |
| Lenovo, Motorola Mobility | If a smaller Type3 codebook size is supported, we prefer Alt 3.  |
| WILUS | Alt 1 or Alt 3.  |
| Spreadtrum | Prefer Alt.1 or Alt.3. |

# SPS HARQ skipping & payload size reduction (for skipped & non-skipped SPS PDSCH)

In this section, the company positions on the support as well as the related proposed Rel-17 enhancements to enable SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCH and SPS payload size reduction (of ‘non-skipped’ SPS PDCH) are summarized. During RAN1#103-e, the following further down-selection of techniques has been agreed:

***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

It should be noted that the NACK skipping procedure for SPS PDSCH for skipping and non-skipped SPS basically is to be regarded as a single technique, as it had been clarified that no identification of skipped SPS PDSCH by the UE is to be assumed. Therefore, it will simply the handling (as proposed by the moderator) to discuss all of these in a single section in here – i.e. considering all 5 proposed features to reduce SPS HARQ in here.

Based on company inputs the following support and details have been provided:

1. **NACK skipping for SPS PDSCH (Alt. 1 for skipped / Alt. 2 for non-skipped SPS PDSCH) – 19x Yes, 4x No**
	* **Yes (19):** ZTE [1], OPPO [2], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3],Ericsson [4], CAICT [5], vivo [7], Nokia [10], Spreadtrum [11], China Telecom [14], TCL [15], NEC [16], ETRI [21], Samsung [23], Interdigital [24], Sharp [27], WILUS [29]
	* **No (3):** Mediatek [8], Panasonic [19] (motivation to be clarified), DOCOMO [28], Sony [12], Lenovo/Motorola Mobility [18]
	* **FFS (-):**
	* **Details**:
		+ PUCCH transmission is skipped if PUCCH to only to carry NACK for SPS PDSCH(s) configured for NACK skipping: OPPO [2], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Ericsson [4], CAICT [5], vivo [7], Nokia [10], China Telecom [14], NEC [16], Samsung [23], Interdigital [24], WILUS [29]
		+ FFS is only NACK for SPS PDSCH(s) is to be multiplexed with UCI other than HARQ-ACK: CAICT [5]
		+ NACK skipping is separately configurable for each SPS configuration: Nokia [10], WILUS [29]
		+ NACK skipping should be jointly configured for all SPS configurations: Spreadtrum [11]
		+ Skipping limited to a number of consecutive instances: Moto/Len [18]
		+ Only applicable when one SPS HARQ-ACK bit is present: ETRI [21]
2. **Dynamic indication of skipped SPS PDSCH occasions (Alt. 3 for skipped SPS PDSCH) – 4x Yes, 8x No, 1x FFS**
	* **Yes (4):** Sony [12] (using MAC CE), CMCC [20] (DCI or MAC CE), Qualcomm [26], DOCOMO [28]
	* **No (8):** Ericsson [4], CATT [6], Mediatek [8], Intel [9], Nokia [10], Panasonic [19] (motivation to be clarified), Samsung [23], vivo
	* **FFS (1):** NEC [16]
	* **Details:**
		+ Using MAC CE: Sony [12], CMCC [20]
		+ Using DCI to indicate: CMCC [20], Qualcomm [26] (indicating one or more empty SPS PDSCH), DOCOMO [28]
			- one or more empty SPS PDSCH: Qualcomm [26], DOCOMO [28] (incl. time-line / pattern)
		+ Using DM-RS to indicate - special DM-RS sequence instead of SPS PDSCH DM-RS sequence: Qualcomm [26]
3. **ACK skipping for SPS PDSCH (NACK-only, Alt. 1 for ‘non-skipped’ SPS PDSCH) - 11x Yes, 4x No, 2x FFS**
	* **Yes (11):** ZTE [1], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], LGE [13], TCL [15], Panasonic [19], Xiaomi [22], Interdigital [24], WILUS [29]
	* **No (3):** Ericsson [4], Mediatek [8], Nokia [10], Sony [12], Lenovo/Motorola Mobility [18]
	* **FFS (2):** Spreadtrum [11], DOCOMO [28]
	* **Cons:** gNB may operate with higher target BLER (different operation strategies, Ericsson [4])
	* **Details:**
		+ PUCCH transmission is skipped if PUCCH to only to carry ACK for SPS PDSCH(s) configured for ACK skipping: Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], WILUS [29]
		+ Skipping limited to a number of consecutive instances: Moto/Len [18]
		+ Limited to one or 2 bits HARQ-ACK case: Panasonic [19], Interdigital [24]
		+ Configured per SPS configuration: WILUS [29]
4. **HARQ bundling / compression for SPS PDSCH (Alt. 3 for ‘non-skipped’ SPS PDSCH) - 9x Yes, 2x No, 1x FFS**
	* **Yes:** ZTE [1], OPPO [2], Intel [9], TCL [15] (for jitter handling), ETRI [21], Xiaomi [22], Apple [25], Qualcomm [26], DOCOMO [28] (if dynamic skipping indication is supported)
	* **No:** Ericsson [4], Mediatek [8]
	* **FFS:** Nokia [10] (continue discussion)
	* **Cons:** Bundling of several SPS where not all are used will lead to NACK (ZTE [1]), if more than process used within the bundle ACK is unclear (Sony [12])
	* **Details:**
		+ The HARQ-ACK codebook for SPS PDSCHs is determined based on the HARQ processes of the multiple SPS PDSCH resources associated with the same PUCCH: OPPO [2]
		+ Multiple SPS configurations are configured to share one HARQ-ACK bit: OPPO [2], Intel [9]
		+ Bundling based on HARQ process IDs: Intel [9]
		+ Include the number of ‘ACK’s with the bundle (e.g. using CS of PUCCH format 0): Sony [12]
		+ Configure a time window / set of SPS configurations for bundling of more than one bit: ETRI [21]
		+ Dynamic triggering using MAC CE / DCI: Xiaomi [22]
		+ **N SPS PDSCH within a jitter window,** $⌈log\_{2}(2×N+1)⌉$ **bits are used for** $2×N+1 $**code states which include the successful/failed decoding at one of those N occasions or no detection of PDSCH at any of those N occasions: Apple [25]**
		+ **compress multiple messages in HARQ-ACK codebook with small probability into a single message: Qualcomm [26]**
5. **HARQ-ACK disabling /skipping for certain SPS configurations (Alt.4 for non-skipped SPS PDSCH):** **6x Yes, 3x No, 1x FFS**
	* **Yes (6):** ZTE [1], OPPO [2], CATT [6], Nokia [10], Xiaomi [22], Interdigital [24], Lenovo/Motorola Mobility [18]
	* **No (2):** Ericsson [4], Mediatek [8], Sony [12]
	* **FFS (1):** DOCOMO [28]
	* **Cons:** Bundling of several SPS where not all are used will lead to NACK (ZTE [1]),
	* **Details:**
		+ Do not include in Type 1 CB and remove the TDRA entry also from the Type 1 CB: ZTE [1]
		+ Include only in Type 1 CB: Nokia [10]
		+ Enable / disable using MAC CE / DCI: Xiaomi [22]

## 4.1 First round of email discussions

*Moderator comments:*

The following support / not support for the 5 different techniques have been indicated by the different companies:

* **NACK skipping for SPS PDSCH – 19x Yes, 4x No**
* **Dynamic indication of skipped SPS PDSCH occasions – 4x Yes, 7x No, 1x FFS**
* **ACK skipping for SPS PDSCH - 11x Yes, 4x No, 2x FFS**
* **HARQ bundling / compression for SPS PDSCH - 9x Yes, 2x No, 1x FFS**
* **HARQ-ACK disabling /skipping for certain SPS configurations - 6x Yes, 3x No, 1x FFS**

The moderator would like to in addition note the following:

* The two proposed features of **NACK and ACK skipping seems to have rather broad support** and as indicated by several companies are envisioned for different SPS operation use cases. There seems to be **common understanding on how to operate these features** with certain details to be still clarified, such as a limitation in the number of bits as well as the RRC configuration details. Therefore, the moderator feels confident that companies should have sufficient knowledge to be able to make a technically founded decision on the support of these two features and therefore **proposes to agree on the support of both of these features**.
* **HARQ bundling / compression for SPS PDSCH seems to have a rather good support.** But in contrast to e.g. ACK or NACK skipping maybe some **further discussions on the details (i.e. how to operate this) will be needed** before being able to make a technically founded decision on the support. Therefore, the moderator suggests to try to **clarify further the operation of this feature during (at least) the first meeting week**.
* About **2/3 of the companies** providing input **indicated support for** **HARQ-ACK disabling /skipping for certain SPS configurations.** As there had been less feedback overall, it is **suggested to not discuss this during the first meeting week.**
* There seems to be **more companies saying to not support dynamic indication of skipped SPS PDSCH**. The moderator therefore suggests to **not discuss this during the (at least) first meeting week**.

Please provide your views on the following two proposals:

**FL Proposal 4.1: Support ‘NACK skipping’ for SPS PDSCH, based on the following operation:**

* **A PUCCH transmission is skipped by the UE if the PUCCH is only carrying SPS PDSCH NACK(s) associated with SPS PDSCH configurations configured for NACK skipping**
* **FFS: Additional details including e.g. RRC configuration details, potential additional restrictions,…**
* **Note: ‘NACK skipping’ assumes inherently no identification of a skipped SPS PDSCH by the UE**
* ***Note: This does not preclude the support of additional methods to support HARQ-ACK skipping / payload size reduction for skipped or non-skipped SPS PDSCH***

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 4.1  | vivo, OPPO,Xiaomi, InterDigital, Spreadtrum |
| Do not support NACK skipping in Rel-17 | MediaTek, Sony, DCM, CATT, Panasonic, WILUS |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | The following reasons show that the potential enhancement is very marginal: * For periodic traffic, the SPS PDSCH is transmitted in all the SPS occasions. Thus, the probability of having skipped SPS PDSCH (and hence a NACK) is very low, limiting the advantage of skipping the HARQ feedback for a “skipped” SPS-PDSCH.
* For aperiodic traffic, DG-PDSCH is more spectrally efficient way compared to SPS-PDSCH. For DL, as the PDCCH and PDSCH can be FDMed or have no gap at all, the scheduling DCI does not cause delay compared to UL transmission. Thus, using SPS-PDSCH for aperiodic traffic in not a typical scenario.
* Skipping the SPS HARQ could save some of the PUCCH resources, but it is not expected that the PUCCH to be the bottleneck in this case, as the PUCCH resources will be very small compared to the PDSCH resources.
* The PUCCH resource will be reserved to the UE, even if the UE skipped the HARQ feedback. Therefore, there is no gain in terms of saving UL resources.
 |
| Sony | PUCCH resource is anyhow reserved for HARQ-ACK.All NACKs in a PUCCH is rare. |
| DCM | We think the use case for NACK skipping is rather limited since HARQ-ACK PUCCH can be skipped only when the PUCCH only include SPS HARQ-ACK with all NACK.  |
| Samsung | Support NACK skipping in general as SPS PDSCH is often not transmitted (otherwise, the NACK probability is small and the proposal can be skipped). Do not agree with the “per SPS PDSCH configuration” for NACK skipping – it makes no sense.  |
| Apple | Reducing PUCCH overhead is just one aspect, another aspect is PDSCH demodulation effort. If skipping is based on NACKs for all demodulated PDSCHs, UE already consumes power for non-existing PDSCHs.  |
| Intel | Neutral – don’t see much benefits, however, don’t see much work to enable dropping of a PUCCH with all NACKs |
| CATT | Marginal gain can be achieved with this enhancement. |
| Panasonic | We share same view with DOCOMO. |
| Lenovo, Motorola Mobility | We support skipping of HARQ-ACK feedback (both ACK and NACK) for a consecutive number of instances. Skipping for the consecutive number of instances would avoid any ambiguity for HARQ-ACK codebook construction. |
| WILUS | Not sure how much gain is achieved with “NACK” skipping only for All NACK of SPS HARQ-ACK.  |
| Spreadtrum | Support NACK skipping to reduce UE encoding burden and reduce UL interference, and we agree with Samsung that “per SPS PDSCH configuration” should be revisited. |

**FL Proposal 4.2: Support ‘ACK skipping’ for SPS PDSCH, based on the following operation:**

* **A PUCCH transmission is skipped by the UE if the PUCCH is only carrying SPS PDSCH ACK(s) associated with SPS PDSCH configurations configured for ‘ACK skipping’**
* **FFS: Additional details including e.g. RRC configuration details, potential additional restrictions,…**
* ***Note: This does not preclude the support of additional methods to support HARQ-ACK skipping / payload size reduction for non-skipped SPS PDSCH***

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 4.1  | InterDigital |
| Do not support NACK skipping in Rel-17 | Vivo, MediaTek, OPPO, Sony, Intel, CATT, WILUS, Spreadtrum |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| vivo | Different from NACK skipping that it is motivated by over-provision of the SPS resources to resolve the periodicity misalignment and to reduce the latency for IIoT traffic, the ACK skipping has no motivation for HARQ-ACK enhancements specific to SPS, for example, the ACK skipping can be used for dynamic scheduled PDSCH.In addition, for ACK skipping, the DTX-to-ACK error would degrade the reliability performance. |
| MediaTek | It will impact the feedback reliability because of the DTX-to-NACK and ACK-to-NACK errors. |
| OPPO | Not support. Benefit from ACK skipping is not clear for us. Moreover, it is not clear to harmonize ACK skipping and NACK skipping. |
| Sony | gNB cannot distinguish between a missed PDSCH and an ACKed PDSCH. |
| DCM | If non-skipped SPS is accurately identified, ACK is dominant in URLLC use case, which means ACK skipping can skip most SPS HARQ-ACK PUCCHs. But as mentioned by other companies, DTX-to-NACK may impact the performance. So we think ACK skipping needs FFS. |
| Samsung | Further discussion is needed (this is “proposal 4.2” for ACK, not NACK, skipping) |
| Intel | For this feature it may not be sufficient to say that there could be services which can sustain detection errors. At this point, the probability to substantially degrade a URLLC service due to DTX-to-ACK errors does not allow to proceed in this direction. |
| CATT | Similar view as MediaTek and Intel. |
| Panasonic | Although our initial thinking is to support ACK skipping is beneficial in URLLC operation, I understand that there is the issue on DTX-to-ACK error. Further discussion is needed. |
| WILUS | There is potential miss-understanding of DTX (missing PUCCH) and ACK (skipping PUCCH).  |

**Further details of ACK and NACK skipping:**

Looking at the details of ACK and NACK skipping, the first thing that would need to be further discussed is how to enable the ACK or NACK skipping procedure. Some companies in their discussions suggested to support the configuration per SPS configuration whereas at least one company suggested to have the configuration for all SPS configurations jointly (i.e. configuration per UE).

Therefore, companies are suggested to provide their support below directly:

**Question 4.1: The ACK or NACK skipping of SPS PDSCH is enabled by**

* **Option 1: RRC configuration per SPS configuration (i.e. within *sps-config*)**
	+ **Supporting companies:** Nokia, WILUS, vivo, Nokia/NSB …
* **Option 2: a single RRC configuration applies to all SPS PDSCH configurations**
	+ **Supporting companies:** Spreadtrum, DCM, …
* **Option 3: Other enabling methods** (details to be provided by supporting companies in the table below)
	+ **Supporting companies:**  …

|  |  |
| --- | --- |
| *Company* | *Option 3 – other proposed method to enable ACK or NACK skipping* |
| vivo | Support option 1.  |
| OPPO | Option 1 is preferred due to flexibility. |
| Xiaomi | We prefer option 1  |
| DCM | Option 2 is preferred. As most companies’ common understanding is that “PUCCH transmission is skipped if PUCCH to only to carry NACK for SPS PDSCH(s) configured for NACK skipping”, option 1 will further limit use case of NACK skipping. For example, if one SPS HARQ-ACK CB includes HARQ-ACK for SPS configuration which is not configured for ACK/NACK skipping, PUCCH can’t be skipped even though other SPS HARQ-ACK bits are corresponding to SPS configurations configured for ACK/NACK skipping and all NACK for the SPS HARQ-ACK CB. |
| InterDigital  | We support Option 1. |
| Lenovo, Motorola Mobility | Option 1 is preferred for more flexibility. |
| WILUS | If ACK or NACK skipping is supported, we prefer option 1. |
| Spreadtrum | Option 2 is preferred. |

There had been suggestions by some companies to restrict the ACK or NACK skipping to e.g. 1 or 2 bits overall or the skipping to be limited to a number of consecutive instances. Companies to provide input on the need of such restrictions.

Therefore, companies are suggested to provide their support below directly:

**Question 4.2: The ACK or NACK skipping of SPS PDSCH, the following restrictions are seen as needed**

* **Option 1: limiting the skipped to a limited number of HARQ-ACK bits (e.g. 1 or 2)**
	+ **Yes:** ETRI,, …
	+ **No:** Nokia / NSB…
* **Option 2:** **the skipping to be limited to a number of consecutive instances**
	+ **Yes:** Moto/Lenovo, Apple…
	+ **No:** Nokia / NSB , …
* **Option 3: Other restrictions are seen as needed** (details to be provided by supporting companies in the table below)
	+ **Yes:**  …

|  |  |
| --- | --- |
| *Company* | *Option 3 – the following additional restrictions are needed for ACK or NACK skipping* |
| vivo | We would like to understand the necessity and benefits for above restriction firstly.  |
| OPPO | Restriction is not required. |
| DCM | We don’t see the benefit of such limitations. |
| Apple | Option 2 can be supported |
| Panasonic | If the operation in Proposal 4.1 and/or 4.2 is supported, i.e., “a PUCCH transmission is skipped by the UE if the PUCCH is only carrying SPS PDSCH NACK(s)/ACK(s) associated with SPS PDSCH configurations configured for NACK/ACK skipping”, we think the restriction is not required. |
| Lenovo, Motorola Mobility | Number of consecutive instances for skipping HARQ-ACK can be configured by gNB depending upon of the survival time requirement for an application. If HARQ-ACK feedback is skipped beyond a certain time, the communication service may be considered unavailable after survival time. |
| Spreadtrum | The necessarily of the restriction is not clear.  |

**Further details of HARQ bundling / compression for SPS PDSCH:**

As noted already, at least to the moderator it is not fully clear on how to define the ‘jitter’ window or ‘bundling’ window. Only a few companies provided their input in their contributions, so it is suggested to get input from more companies or give here companies the chance to ask some questions on the methods proposed in the input documents, including:

1. The HARQ-ACK codebook for SPS PDSCHs is determined based on the HARQ processes of the multiple SPS PDSCH resources associated with the same PUCCH: OPPO [2]
2. Multiple SPS configurations are configured to share one HARQ-ACK bit: OPPO [2], Intel [9]
3. Bundling based on HARQ process IDs: Intel [9]
4. Include the number of ‘ACK’s with the bundle (e.g. using CS of PUCCH format 0): Sony [12]
5. Configure a time window / set of SPS configurations for bundling of more than one bit: ETRI [21]
6. Dynamic triggering using MAC CE / DCI: Xiaomi [22]
7. **N SPS PDSCH within a jitter window,** $⌈log\_{2}(2×N+1)⌉$ **bits are used for** $2×N+1 $**code states which include the successful/failed decoding at one of those N occasions or no detection of PDSCH at any of those N occasions: Apple [25]**
8. **compress multiple messages in HARQ-ACK codebook with small probability into a single message: Qualcomm [26]**

**Question 4.3: Companies to provide their input / clarifications / or questions on the details proposed by different companies above (1…8) or provide additional details on how to define the bundling / compression / jitter window and how to perform the bundling/compression.**

|  |  |
| --- | --- |
| *Company* | *SPS HARQ bundling / compressionQuestion on the suggested details (see above), clarifications or any additional comments* |
| OPPO | The HARQ-ACK codebook for SPS PDSCHs is determined based on the HARQ processes of the multiple SPS PDSCH resources associated with the same PUCCH. One example is shown in Figure 1, 8 SPS PDSCH resources are associated with one PUCCH. The SPS resources of SPS configuration 1 are used to transmit HARQ process 6, 7, 8 and 0, and the SPS resources of SPS configuration 2 are used to transmit HARQ process 0, 1 and 2. Considering HARQ process 0 cannot be reused, so only 6 HARQ-ACK bits need to be included in the SPS HARQ-ACK codebook for HARQ process 0/1/2/6/7/8.Figure1: SPS HARQ-ACK codebook determined based on the HARQ processesMultiple SPS configurations are configured to share one HARQ-ACK bit. One example is shown in Figure 2, SPS configuration 1~3 are configured for one service to solve the jitter problem. During each periodicity, at most one SPS PDSCH will be transmitted, then only one HARQ-ACK bit should be fed back for each periodicity. Figure 2: Multiple SPS PDSCH sources share one HARQ-ACK bit in SPS HARQ-ACK codebook |
| Sony | The bundling “window” should not be limited to only jittering. The SPS can be RRC configured to belong to a bundling window.The UE only need to provide the *number* of ACKs in a bundling window. |
| DCM | In our view, HARQ-ACK bundling is performed for each HARQ-ACK CB without changing legacy HARQ-ACK reporting timing determination procedure. For example, UE determines HARQ-ACK bits to be reported in the same HARQ-ACK CB of the slot/sub-slot. Then UE bundles every N HARQ-ACK bits into 1 bit, resulting in M bits in the HARQ-ACK CB, where N can be fixed or M can be fixed. |
| Intel | OPPO provides good example how the CB could be constructed when different SPS occasions are configured to use the same PUCCH resource. There may be no need for explicit “jitter window” or “bundling window”. |
| Lenovo, Motorola Mobility | Although, HARQ-ACK bundling/compression is not our preferred option, however, if option needs to be further considered, then one possible option for determining the bundling window could be configured by network depending up on survival time requirements. |

# 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. There had only be little progress in RAN1, but RAN plenary was able to clarify the focus a bit better based on the following conclusion taken during RAN#90:

***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 **alternatives to support ‘sub-slot type of PUCCH repetition’** have been mentioned by different companies.

* **Alt. 1: Sub-slot based PUCCH repetition** (same start / duration / PUCCH resource in each subslot, one repetition per subslot): 15x, 1x No, 1x FFS
	+ **Yes:** ZTE [1], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Ericsson [4], CATT [6], Nokia [10], Spreadtrum [11], LGE [13], China Telecom [14], Panasonic [19], ETRI [21], Xiaomi [22] (for longer PUCCH formats), Samsung [23], DOCOMO [28]
	+ **No:** Mediatek [8] (…don’t proceed with PUCCH repetition enhancement studies, allow PUCCH to cross the sub-slot boundary instead)
	+ **FFS:** Sony [12]
* **Alt. 2: Back-to-back PUCCH repetition with short formats:** Xiaomi [22] – 1 Yes
	+ *Moderator comment:*back-to-back, i.e. PUSCH repetition Type B PUCCH repletion has been excluded from the WI based on the RAN plenary conclusion above
* **Alt. 3: Repetitions to support different starting point & duration based on PUCCH configuration:** Intel [9] – 1x Yes

**Support PUCCH repetition for short PUCCH formats (F0 & F2):** - 10x Yes

* **Support:** ZTE [1], Ericsson [4], Nokia [10], Spreadtrum [11], China Telecom [14], Panasonic [19], Xiaomi [22], Samsung [23], DOCOMO [28], Xiaomi [22]
* **No support:** -

**Other suggested enhancements for PUCCH repetition** (not limited to ‘sub-slot type PUCCH repetition):

* Dynamic indication of PUCCH repetition factor: Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Ericsson [4], CATT [6] (repetition factor configured for each PUCCH resource), Intel [9] (per triggered PUCCH format), Spreadtrum [11], Panasonic [19] (from Cov. Env. should be applicable here), ETRI [21]
	+ ***Moderator comment:*** *It has been agreed to be supported as part of the Coverage Enhancements WI – therefore, not to be treated / discussed here.*
* Per repetition PUCCH dropping rules concerning overlapping with DG PUSCH: Nokia [10] (FFS)
* Support of sub-slot based PUCCH repetition to be also applicable for SR and/or CSI: Nokia [10] (FFS)
* Enabling multiplexing of different UCI types within a PUCCH repetition bundle: Nokia [10] (FFS)
* Reducing the priority of a repetition according to the number of repetitions that have already been transmitted: Sony [12]
* Discuss multiplexing / prioritization rules: LGE [13]
* Introduce additional PUCCH repetition factors: ETRI [21]
* Support of dynamic bundling for PUCCH repetition to limit the payload size: QC [26]
	+ Incl. gNB configurable compression / bundling threshold or dynamic bundling/compression indication in the DCI

## 5.1 First round of email discussions

*Moderator comments:*

**Sub-slot type of PUCCH repetition**

* There seems to be **strong support (15x Yes, 1x No, 1x FFS) to support sub-slot based PUCCH repetition based on the Rel-15 PUCCH repetition framework (i.e. same start / duration / PUCCH resource in each subslot, one repetition per subslot)**
* One company suggesting back-to-back PUCCH repetition framework, which based on the moderator’s understanding was excluded from the WI scope by the RAN#90 conclusion. 🡪 to be not considered
* One company suggesting a different sub-slot type of PUCCH repetition framework (with different PUCCH resources configured for each repetition)
* Based on this, the **moderator suggest trying to agree on the support of sub-slot based PUCCH repetition** (based on the Rel-16 framework) during this meeting.

**Other suggested enhancements:**

* The support of **PUCCH repetition for shorter PUCCH formats** received rather good support. And if sub-slot based PUCCH repetition is to be supported also for 2OS sub-slots this will be needed. Therefore, moderator **suggesting to agree on the support** on repetition of short PUCCH formats **at least for sub-slot based PUCCH repetition**.
* Many companies mentioned the support of **dynamic PUCCH repetition**. The moderator would like to note here, that the support of dynamic PUCCH repetition indication is **covered in the Coverage Enhancements WI**. Therefore, as this is to be supported in Rel-17 already, there is no need to duplicate the related discussions in this WI / AI. Therefore, the moderator suggests to **not discussing this**.
* There had been **other** **single company proposals** on PUCCH repetition enhancements brought to this meeting. It is suggested to at least **not discuss them during the (at least) first meeting week**

**Based on the discussions during the GTW call – the proposal has been updated trying to address the following comments:**

* Do not refer to the specifications (to not imply a CR/TP, but try to be more generic in the formulation
* Repetition to be limited to HARQ-ACK (other UCI types could still be discussed / FFS)
* Dynamic repetition indication to be supported also for sub-slot PUCCH. Trying to leverage the Cov. Enh. WI outcome as much as possible
	+ ***Moderator comment:*** If the dynamic repetition indication is indicated by a field in the DCI directly, then this can be equally applied for the sub-slot PUCCH. If the dynamic repetition indication would be part of the pucch-resource config (and PRI indicating the repetition factor), then the same applies as basically this would be clearly part of PUCCH config (independently if it is of slot or sub-slot type). So we may need to wait a bit on the outcome of the Cov. Enh. WI discussions there (proposed to put detailed discussions on hold for the moment…)

**Updated FL Proposal 5.1: 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.**

* **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**
* **FFS: sub-slot based PUCCH repetition for other UCI types**
* **FFS: Additional PUCCH repetition enhancements**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 5.1  | Vivo, Xiaomi, Sony, Nokia/NSB, DCM, Samsung, CATT, Panasonic, NEC, Sharp, WILUS, Spreadtrum |
| Do not support sub-slot PUCCH repetition in Rel-17 | MediaTek |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | If the latency allows having sub-slot PUCCH repetition, the UE can be configured with longer sub-slot length. There is no direct comparison between slot-based and sub-slot based PUCCH repetitions. Unlink sub-slot based PUCCH transmission; the UE cannot be configured with slot length more than 14 symbols. Thus, there is no need to extend the slot-based PUCCH repetition to sub-slot. |
| Sony | Note that in Rel-16 sub-slot PUCCH was introduced solely for HARQ-ACK. Hence we should only consider this for HARQ-ACK. |
| Nokia/NSB | Could be limited to HARQ only.  |
| Samsung | It is understood that a benefit may not exist in case semi-static repetitions but the reasons to support are same as for “slot-based” transmissions in case of dynamic repetitions. |
| Intel | With currently available sub-slot configuration of 2 and 7 symbols, we are not sure simple enabling of PUCCH repetitions over sub-slots can bring much benefits.Since MIMO also intends to utilize URLLC repetition framework for multi-TRP, this kind of design may be limiting. For example, in many cases of achieving transmit diversity over repetitions (both multi-TRP and single-TRP), a transient/switching gap is required, which may be in the order of symbols for large sub-carrier spacings. This may only be achieved by inefficient combinations of PUCCH duration less than sub-slot.The above limitation may need to be discussed and avoided by introducing a more general PUCCH repetition framework, as was proposed in our contributions. |
| WILUS | Sub-slot PUCCH repetition should be applied to HARQ-ACK only.  |

**FL Proposal 5.2: Support PUCCH repetition for PUCCH formats 0 and 2 at least for sub-slot based PUCCH repetition.**

* **FFS: Support for slot-based PUCCH repetition**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 5.2  | Vivo, Nokia/NSB, DCM, Samsung, CATT, Panasonic, NEC, Sharp, WILUS, Spreadtrum |
| No | MediaTek |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# Type 1 HARQ codebook based on sub-slot PUCCH config

First, during RAN1#103-e it was clarified that Type 1 CB for sub-slot PUCCH is not supported in Rel-16. Moreover, there had been good support for the feature in Rel-17 overall but it was discussed that further details may need to be clarified before agreeing the support in Rel-17.

Overall, the following on the support in Rel-16 or in Rel-17 based on company inputs in their input contributions can be noted.

**Support for Type 1 HARQ-ACK codebook for sub-slot PUCCH in Rel-17: 16x Yes, 2x No**

* **Support in Rel-17 (16 companies):** ZTE [1], OPPO [2], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Ericsson [4], CATT [6], Nokia [10], Spreadtrum [11], LGE [13], NEC [16], CMCC [20], Samsung [22] (subject to min. specs & implementation effort), Qualcomm [26], DOCOMO [28], WILUS [29]
* **No (2 companies):** Mediatek [8], Xiaomi [22] (‘low priority’)

**Ways to support the Type 1 HARQ-ACK CB for sub-slot PUCCH:**

* ZTE [1]:
	+ *“…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”*
	+ Following steps are proposed:
		- *Divide the PDSCH TDRA in a slot into different SLIV groups (already supported in Rel-15/16);*
		- *Associate a SLIV group with a sub-slot according to the latest end symbol of the PDSCHs in the SLIV group;*
		- *Generate HARQ-ACK information for each SLIV group in each sub-slot and concatenate the HARQ-ACK information to form type1 HARQ-ACK codebook.*
* OPPO [2]: “*For a given subslot, if the last symbols of the PDSCH time resource derived by a TDRA row r is not in the subslot, row r is removed from the cardinality of TDRA rows.”*
* Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3]:
	+ *For example, the associated sub-slots of a given UL sub-slot can be determined based on the configured K1 set, then for each sub-slot the SLIVs whose ending symbols are located in this sub-slot are selected from the configured SLIV set and the SLIV splitting is performed for these SLIVs belonging to the same sub-slot to get the PDSCH occasion per sub-slot.*
* 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.*
	+ *…..further optimization to reduce Type-1 codebook size can be considered*
* CATT [6]
	+ *find all the PDSCH occasions based on the boundary of UL sub-slot so that the redundant HARQ-ACK bit(s) can be removed and all the PDSCH occasions can be included, where a PDSCH occasion is associated with a UL sub-slot if the end of the PDSCH overlaps with the UL sub-slot*
		- *For the case of an UL sub-slot spans multiple DL slots, the loop condition “while ” for Type-1 codebook should be replaced by “while* $n\_{D}<max⁡(2^{μ\_{DL}-μ\_{UL}}/N,1)$*” for HARQ-ACK in a UL sub-slot;*
		- *For the case of one DL slot spans multiple UL sub-slots, only the PDSCH SLIV which falls into the HARQ-ACK multiplexing window are considered to determine the HARQ-ACK codebook, A PDSCH SLIV is associated with a UL sub-slot if the end of the PDSCH overlaps with the UL sub-slot. The HARQ-ACK multiplexing window is determined based on the HARQ-ACK timing set and sub-slot length.*
* Nokia [10]
	+ *The HARQ-ACK multiplexing window is defined based on the HARQ-ACK timing set K1 and sub-slot length.*
		- *The applicable K1 set considering the applicable DCI formats for the PUCCH configuration based on Sec. 9.1.1.1 of TS 38.213 is reused.*
	+ *Definition of the union set of TDRA entries: A PDSCH TDRA is associated with an UL / PUCCH sub-slot if the end of the PDSCH overlaps with the UL sub-slot.*
	+ *The pruning is performed per PUCCH sub-slot based on the TDD configuration (as in Rel-15, but per sub-slot)*
	+ *FFS: additional codebook size optimizations*
* Spreadtrum [11]: *Similar as Rel-16 type 1 codebook, the union set of row indexed of TDRAs are used to determine the PDSCH occasions, including for DCI formats the UE is configured to monitor PDCCH and reference of SLIV if it is configured.*
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 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.*
* LGE [13]
	+ *it is necessary to remove unusable candidate PDSCH reception in type-1 HARQ-ACK codebook from the following cases:*
		- *A K1 value is corresponding to only one DCI format*
		- *A TDRA entry is corresponding to only one DCI format*
* NEC [16]
* *When DL and UL are configured with same numerology, the sub-slot based semi-static HARQ-ACK codebook can be determined based on following three-steps:*
	+ *Step 1: Determine the HARQ-ACK multiplexing window based on the HARQ-ACK timing set and sub-slot length.*
	+ *Step 2: Split the TDRA table into N sub-tables based on the sub-slot length and PDSCH-to UL sub-slot association. N is the number of sub-slots within a slot.*
	+ *Step 3: Do pruning based on TDD configuration and sub-table per sub-slot similar as Rel-15.*
* *When DL and UL are configured with different numerologies, further study the sub-slot based semi-static HARQ-ACK codebook determination.*
* *Optionally, the C-DAI/T-DAI counters can be reused/redefined for the pruned sub-slot based HARQ-ACK codebook (enhanced reliability for URLLC).*
* Samsung [23]
	+ *Determine candidate UL sub-slots and corresponding DL slots for candidate PDSCH receptions based on the HARQ-ACK timing set (sub-slot-level K1) and number of UL sub-slots N per UL slot on top of existing procedure for different DL/UL numerologies.*
	+ *Do pruning based on TDD configuration and SLIVs for each DL slot, wherein the SLIVs end in candidate UL sub-slots*
* Qualcomm [26]
	+ *A PDSCH occasion (i.e., time-domain resource allocation) is associated with an uplink sub-slot that contains the end of the PDSCH occasion.*
* DOCOMO [28]
	+ *…. logical steps proposed in RAN1#103-e can be used for Type-1 HARQ-ACK codebook for sub-slot based HARQ-ACK*
		- *Step 1: Determine the HARQ-ACK multiplexing window based on the HARQ-ACK timing set and sub-slot length.*
		- *Step 2: If a UL sub-slot in the HARQ-ACK window spans multiple DL slots, create a new TDRA table which is the union of the configured TDRA table and the configured TDRA table offset by 14 symbols.*
		- *Step 3: Split the TDRA table into N sub-tables based on the sub-slot length and PDSCH-to UL sub-slot association. A PDSCH TDRA is associated with a UL sub-slot if the end of the PDSCH overlaps with the UL sub-slot. N is the number of sub-slots within a slot.*
		- *Step 4: Do pruning based on TDD configuration and sub-table per sub-slot similar as Rel-15.*
* WILUS [29]
	+ *For a given (****sub-slot-level****) K1 value k1, find the DL slot corresponding to the UL sub-slot n-k1.*
		- *Validity of each SLIV in a TDRA table R for the DL slot is checked. The invalid SLIVs are removed from the TDRA table R.*
			* *The validity is checked based on semi-static UL/DL configuration, i.e., if a symbol corresponding to an SLIV overlaps with semi-static UL symbol, then the SLIV is invalid.*
			* *And the validity is further checked based on the last symbol of an SLIV, i.e., the last symbol of an SLIV does not overlaps with the UL sub-slot n-k1, then the SLIV is invalid.*
		- *If the TDRA table R is not empty, then generate type-1 HARQ-ACK codebook for the DL slot.*
			* *If a UE has no capability to receive more than one unicast PDSCH per DL slot, then one HARQ-ACK occasion is added to the type-1 HARQ-ACK codebook.*
			* *If a UE has capability to receive more than one unicast PDSCH per DL slot, overlapping of SLIVs are further checked and then find a set of SLIVs to be represented as one HARQ-ACK occasion.*

Other suggested Type 1 CB enhancements – not necessarily related to Type 1 CB for sub-slot PUCCH:

* Reduce redundant bits – by taking the configured DCI monitoring occasions (e.g. for DCI format 1\_2) into account: CATT [6] (Figure in Appendix [6])
* Configuration of ‘feedback TDRA’ table for Type 1 CB size reduction: Nokia/NSB [10] (Figures see Appendix [10])
* Using DAI for Type 1 CB size reduction: NEC [16] (use existing C-DAI and re-defined T-DAI for Type 1 CB)
* The sub-slot based Type-1 HARQ-ACK codebook ACK/NACK bits will only be present if the corresponding slot or sub-slot has at least one PDCCH transmission: NEC [16]
* Enhancements for multi-TRP PDSCH repetition: Samsung [23] (Figure see Appendix [23])

## 6.1 First round of email discussions

*Moderator comments:*

* Based on companies’ position, there is a **large majority of companies suggesting supporting Type 1 CB for sub-slot PUCCH in Rel-17**. But looking at the details provided, there seem to be a common understanding on the PDSCH TDRA to UL/PUCCH sub-slot association. Otherwise, the proposals from different companies seems to be mainly diverging in terms of how to describe this. It should be noted here, that it seems to be sufficient to agree on the properties of the Type 1 CB for sub-slot PUCCH and the detailed implementation could be left to the editor when providing the first version of the Rel-17 38.213 specifications. Therefore, it is **proposed in the first round trying to agree on the support of Type 1 CB for sub-slot PUCCH with some baseline property(ies)**
* After having clarify on the support based on baseline properties, **additional needed Type 1 CB properties** for sub-slot PUCCH to be clarified could be discussed in the **next phase of email discussion**.
* **Additional Type 1 CB enhancements** have been proposed by different companies. It is suggested here to **not discuss them in the early phases of email discussions** during RAN1#104-e.

Therefore, the following proposal is suggested:

**FL Proposal 6.1: 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 UL /PUCCH sub-slot.**
* **FFS: Additional properties that may need clarification**
* **FFS: Other Type 1 HARQ-ACK CB construction enhancements (for sub-slot based &/ slot based HARQ-ACK feedback)**

|  |  |
| --- | --- |
|  | *List of companies* |
| Support proposal 6.1 (at least in principle) | OPPO, Nokia / NSB, DCM, Samsung, CATT, NEC, Sharp, WILUS, Spreadtrum |
| Do not support Type 1 CB for sub-slot PUCCH in Rel-17 | MediaTek,Xiaomi |

Addition comments can be provided below (especially for companies not supporting the proposal at all, not even in principle):

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | We don’t see Type-1 HARQ-ACK codebook suitable for URLLC applications, the high payload of the feedback will jeopardize the reliability. Thus, it will only add UE implementation complexity without real benefits. |
| Xiaomi | Sub-slot based Type 1 codebook is already supported. As to the miss detection performance of Type 1 and Type 2 HARQ-ACK codebook, a typical case for URLLC HARQ-ACK codebook is that it only contains HARQ-ACK information of one actually scheduled PDSCH. And if the one PDSCH is miss detected, UE will not feedback any HARQ-ACK information no matter Type 1 or Type 2 codebook is applied. In this case, Type 1 and Type 2 codebook shows no difference on miss detection performance.  |
| Samsung  | We want to ask for the clarification for the intention of “a PDSCH TDRA is associated with a UL /PUCCH sub-slot if the end of the PDSCH overlaps with the UL /PUCCH sub-slot.” In our understanding, it just simply clarifies how to determine the candidate PDSCH reception occasions for sub-slot based PUCCH by replacing existing UL slot with UL sub-slot. It does not imply the PDSCH TDRA grouping per DL sub-slot. If yes, we support the proposal. If it implies the PDSCH TDRA grouping, we object to it, because it has large standard impact without any benefit.  |
| WILUS | We are generally fine with this proposal. But, we think it is not necessary to define complicate TDRA grouping (according to UL sub-slots) or TDRA extension (to cover different DL/UL numerology). To minimize specification impacts, validity of a SLIV in TDRA can be further checked based on the end of the SLIV and UL sub-slot.  |
|  |  |

# PUCCH carrier switching for HARQ feedback

In the RAN1#103-e meeting, the following agreement was reached.

*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.*

The following feedback on how to **support PUCCH carrier switching in Rel-17** was received:

* **Alt. 1 - Dynamic indication of PUCCH carrier switching: 6x Yes, 2x No, 1x FFS**
	+ **Support (6) :** ZTE [1], Huawei / HiSi [3], BUPT [3], China Southern Power Grid [3], Mediatek [8], APT [17]
	+ **No (2):** Ericsson [4], vivo [7]
	+ **FFS (1):** Nokia [10] (focus of further discussions on the support)
	+ **Cons:** large specs impact & unclear benefit (Ericsson [4]), missed DCI indication (QC [26]),
	+ **Details:**
		- PUCCH configuration could be a combination of ‘per PUCCH group’ and ‘per PUCCH carrier’: Mediatek [8]
		- PUCCH carrier selection reliability can be helped by not changing the indicated PUCCH carrier index : Mediatek [8]
		- Separate TPC configuration and TPC loop for PUCCH per PUCCH carrier: Mediatek [8]
		- FFS if dynamic switching between different PUCCH cell groups is allowed: APT [17]
* **Alt. 2 – PUCCH cell switching based on semi-static configuration:** **4x Yes, 1x No, 3x FFS**
	+ **Support (4):** Ericsson [4], NEC [16], Moto/Len [18], Qualcomm [26]
	+ **FFS (3):** China Telecom [14] (based on predefined rules, if supported), APT [17] (if dynamic indication is not supported), DOCOMO [28]
	+ **No (1):** vivo [7]
	+ **Details:**
		- Configuration of pucch-Cell on PCell to indicate another serving cell within the same cell group to use for PUCCH: Ericsson [4]
		- Based on pre-defined rules: China Telecom [14], APT [17], Moto/Len [18] (chose carrier with lowest latency), Qualcomm [26] (applicable cell with lowest cell index, PCC as reference numerology)
		- Using the k1 of a reference numerology and cell priority: NEC [16]
		- Limited to a single PUCCH transmission at time within a PUCCH cell group (i.e. no PUCCH carrier diversity transmission): Qualcomm [26]
		- Further study based on the outcome of Rel-16 processing order for Intra-UE mux/prio & UL cancelation due to TDD configuration: DOCOMO [28]

**Additional provided input on the PUCCH carrier switching:**

* APT in [17] proposes as a compromise to support both, Alt. 1 and Alt. 2 (based on configuration).
* Should be limited to inter-band CA in Rel-17: Samsung [23]
* Should be applicable for HARQ; SR/LLR & CSI: Samsung [23]
* HARQ-ACK timing indicator counts only slots with PUCCH resources for PUCCH carrier switching: Samsung [23]

## 7.1 First round of email discussions

*Moderator comments:*

Looking at the feedback provided, companies seem to be split between dynamic indication and semi-static operation. It seems the operation of the dynamic indication seems to be more clear (incl. the disadvantages of such as DCI overhead & missed detection issues) – whereas the moderator has the feeling that still some more clarification on Alt. 2 would be needed for the group to be able to make a clear technical decision which of these alternatives to pursue further.

At least it seems, that from the input given on Alt. 2 there currently seem to be at least two flavors there:

* Alt. 2A having a semi-statically ‘fixed’ UL serving cell carrying the PUCCH (as e.g. based on the proposal by Ericsson)
* Alt. 2B by applying certain rules on how to determine the applicable cell for PUCCH transmission (from the set of possibly applicable cells). This will allow to have a dynamic change of the PUCCH cell based on these rules. Similar as in the discussions on SPS HARQ-ACK dropping, specifically it would need to be discussed on how such rules at least about would interact with semi-static DL & flexible symbols. Or how the UE would determine the cell in case of different SCS, etc.

For the first round it is suggested to gather a bit more input on Alt. 2A (fixed PUCCH cell based on RRC configuration which can be another cell than Pcell) and Alt. 2B (dynamic PUCCH cell switching based on certain ‘rules) or any other options for PUCCH cell switching based on semi-static configuration not covered by 2A & 2B are envisioned. And slightly more input on the rules for Alt. 2B supporting companies would be appreciated, such as interaction with the TDD pattern, handling of different SCS on different UL serving cells, etc.

**Question 7.1: Related to PUCCH cell switching based on semi-static configuration, please provide your input on the Alt. 2A (fixed PUCCH cell based on RRC configuration which can be another cell than Pcell) and Alt. 2B (dynamic PUCCH cell switching based on certain ‘rules) including the interaction with TDD configurations as well as handling of different SCS. If your envisioned operation is neither captured by Alt. 2A or Alt. 2B, please provide further details.**

|  |  |
| --- | --- |
| *Company* | *Comments* |
| MediaTek | In our view, similar to the approach adopted for the other proposals, we should focus on commonality between Alt-1 and Alt-2, which is supporting PUCCH carrier switching in Rel-17. The rest of the details, such as dynamic or semi-static switching, can be discussed in later stages. |
| DCM | For Alt 2A, we think one possible method is that gNB configures a PUCCH cell timing pattern, e.g. indicating Pcell is used for some time and another PUCCH cell to be used in other time. The pattern is configured based on slot format configuration of different CCs.For Alt 2B, a rule can be defined for PUCCH cell determination. For example, UE determines HARQ-ACK reporting timing as in R15/16, and if the PUCCH on PCell overlaps with invalid symbol, UE will select another PUCCH cell with corresponding HARQ-ACK reporting timing and the PUCCH on the cell doesn’t overlap with invalid symbol. From gNB complexity perspective, it’s better not to consider dynamic SFI indication for the “invalid symbol” definition.  |
| Samsung | Alt. 2B - has to be dynamic – e.g. based on indicated PUCCH resource - as UCI payload is dynamic and PUCCH resource is dynamic.  |
| Apple | Just making a choice between 2A and 2B, 2A is less complicated than 2B. But the UE implementation complexity for PUCCH switching even with 2A should be addressed first  |
| NEC | For Alt.2B, a rule can be defined as follows:* A set of cells with different priority levels are configured for PUCCH transmission by RRC within a PUCCH cell group.
* UE firstly determines the slot for PUCCH transmission based on the indicated k1 value with a reference numerology (e.g., largest SCS) when different SCS are configured for the multiple PUCCH cells.
* According to the descending order of priority, UE finds a cell that having enough valid symbols corresponding to the determined slot. The valid symbols at least include configured UL symbols, FFS flexible symbols.
 |
| Lenovo, Motorola Mobility | Alt 2B. If PUCCH on PCell overlaps with an invalid symbol(s), UE can choose to transmit HARQ-ACK feedback in one of configured PUCCH carriers within the maximum allowed HARQ-ACK feedback delay where the earliest available/valid PUCCH is.  |
|  |  |
|  |  |

# Other suggested HARQ-ACK feedback enhancements

## 8.1 CB size reduction for HP HARQ-ACK: Single HARQ-ACK bit per TB for HP HARQ-ACK CB

As discussed by Huawei / HiSi [3], BUPT [3], China Southern Power Grid in [3], in Rel-15, the gNB can use higher layer signaling to configure the maximum number of code words i.e. {1 or 2} that a single DCI (i.e. DCI format 1\_1) may schedule. If the maximum number of code words is configured as 2, then it means that DCI format 1\_1 can schedule 1 or 2 code words. In order to avoid misaligned HARQ-ACK codebook sizes between the gNB and the UE, due to potential DCI miss detection, the HARQ-ACK codebook is constructed based on 2 code words no matter if the DCI schedules one or two code words. It should be noted here, that DCI format 1\_2 supports only single codeblock PDSCH scheduling, meaning that always two bits of HARQ-ACK will be generated (if maximum number of codewords is configured as 2) even when only scheduling HP traffic with DCI format 1\_2.

**Regardless of the configured maximum number of code words, HARQ-ACK codebook construction based on only one code word could be considered for HARQ-ACK codebook with high priority in Rel-17.**

## 8.2 Retain PUSCH reception robustness with increased number of (SPS) HARQ-ACK bits

Samsung discussed in [23], it is discussed that in Rel-15, if UE multiplexes HARQ-ACK bits on PUSCH, and the number of HARQ-ACK bits is not greater than 2, UE reserves REs for up to 2 HARQ-ACK bits to avoid PUSCH decoding error due to an incorrect HARQ-ACK payload size caused by a missed PDCCH. In other words, this targets to handle vulnerability with up to 2 DG HARQ-ACK bits; 1 or 2 DG HARQ-ACK bits depending on the existence of SPS HARQ-ACK bit. In Rel-16, while such vulnerability with small number of DG HARQ-ACK bits still needs to be handled, multiple active SPS configurations and smaller SPS periodicity may result in multiple SPS HARQ-ACK bits. As a result, the incorrect HARQ-ACK payload size caused by small number of DG HARQ-ACK bits may happen for a larger number of HARQ-ACK bits when many SPS HARQ-ACK bits are present.

In this sense, the condition of 2 bits is not suitable and hence it needs enhancement, for example, increasing the threshold values to more than 2 bits (i.e. more reserved REs) in order to improve reliability of HARQ-ACK which could be transmitted on PUSCH.

**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.**

## Jitter window for SPS occasions

Apple in [25] discusses using a jitter window instead of NACK skipping for ‘skipped’ SPS handling, the introduction of a jitter window around a nominal SPS occasion



Figure 2: Jitter window to limit UE demodulation effort and HARQ generation

## Different TX power levels for ‘ACK’ and ‘NACK’

Mediatek in [8] based on extensive evaluations in Sec. 3 identified (based on different DTX-to-ACK, NACK-to-ACK etc. performance) that the current operation may not be sufficient. The interested reader is refered to the TDoc there directly.

What is proposed:

***Support different PUCCH transmission power levels depending on whether ACK or NACK is transmitted.***

## 8.5 MAC CE based switching between different sub-slot PUCCH configurations

In R16, the sub-slot configuration is RRC configured which does not allow for a more frequent change of the applicable sub-slot configuration of a PUCCH config (i.e. only slow adaptation possible).

QC in [26] proposes that the gNB could configure multiple sub-slot configurations to the UE by RRC, which can then be (more) dynamically selected based on MAC CE signaling.



**MAC-CE based sub-slot configuration switch**

# References

1. R1-2100101 Discussion on HARQ-ACK enhancements for eURLLC ZTE
2. R1-2100181 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO
3. R1-2100226 UE feedback enhancements for HARQ-ACK Huawei, BUPT, China Southern Power Grid, HiSilicon
4. R1-2100268 HARQ-ACK Enhancements for IIoT/URLLC Ericsson
5. R1-2100302 UE feedback enhancements for HARQ-ACK CAICT
6. R1-2100376 UE feedback enhancements for HARQ-ACK CATT
7. R1-2100436 HARQ-ACK enahncements for Rel-17 URLLC vivo
8. R1-2100574 On UE feedback enhancements for HARQ-ACK MediaTek Inc.
9. R1-2100649 UE HARQ feedback enhancements for URLLC/IIoT Intel Corporation
10. R1-2100728 HARQ-ACK Feedback Enhancements for URLLC/IIoT Nokia, Nokia Shanghai Bell
11. R1-2100803 Discussion on physical Layer feedback enhancements Spreadtrum Communications
12. R1-2100855 Considerations on HARQ-ACK enhancements for URLLC Sony
13. R1-2100880 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics
14. R1-2100911 Discussion on UE feedback enhancements for HARQ-ACK China Telecom
15. R1-2100920 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.
16. R1-2100948 UE feedback enhancements for HARQ-ACK NEC
17. R1-2100968 Discussion on UE feedback enhancements for HARQ-ACK Asia Pacific Telecom, FGI
18. R1-2100993 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility
19. R1-2101013 Discussion on UE feedback enhancements for HARQ-ACK Panasonic Corporation
20. R1-2101039 Discussion on UE feedback enhancements for HARQ-ACK CMCC
21. R1-2101075 UE feedback enhancements for HARQ-ACK ETRI
22. R1-2101114 UE feedback enhancement for HARQ-ACK Xiaomi
23. R1-2101201 On HARQ-ACK reporting enhancements Samsung
24. R1-2101290 HARQ-ACK enhancements for IIoT and URLLC InterDigital, Inc.
25. R1-2101378 Views on UE feedback enhancements for HARQ-ACK Apple
26. R1-2101459 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated
27. R1-2101539 UE feedback enhancements for HARQ-ACK Sharp
28. R1-2101612 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
29. R1-2101675 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.

# Appendix: 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

# Appendix: Summary of companies’ proposals

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

### R1-2100101 Discussion on HARQ-ACK enhancements for eURLLC ZTE

***Observation 1:*** *The cancelled HARQ-ACK codebook can be triggered for transmission at the earliest after the conflict is determined.*

***Proposal 1:*** *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.*

***Proposal 2:*** *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 3:*** *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 4:*** *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 5:*** *Both NACK skipping (ACK only) and ACK skipping (NACK only) should be supported, and the feedback mode can be configured by the base station.*

***Proposal 6:*** *For SPS HARQ payload size reduction, support Alt. 3 (HARQ bundling) and Alt. 4 (HARQ-ACK disabling /skipping for certain SPS configurations)*

* *For Alt. 3, the bundling mechanism for SPS configuration should be further studied.*
* *For Alt. 4,*
	+ - *If an SPS configuration is disabled for feedback, when the UE constructs a semi-static HARQ-ACK codebook corresponding to only the SPS configuration, the semi-static HARQ-ACK codebook should not include the SPS configuration disabled for feedback.*
		- *If an SPS configuration is disabled for feedback, when the UE constructs a semi-static HARQ-ACK codebook corresponding to the SPS configurations and DG PDSCH, the semi-static HARQ-ACK codebook should not include the PDSCH TDRA corresponding to the SPS configuration.*

***Proposal 7:*** *Sub-slot based PUCCH repetition enhancements is supported:*

* *Similar mechanism of the slot-based PUCCH repetition in Rel-15/16 can be applied to the sub-slot based PUCCH repetition, and the PUCCH format includes PUCCH F0/F2.*

***Proposal 8:*** *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.*

***Proposal 9:*** *For the transmission of the dropped HARQ-ACK codebook, Alt. 3/Alt. 4 should be supported.*

* *Alt. 3: DCI scheduling PUSCH to carry dropped HARQ-ACK codebook.*
* *Alt. 4: DCI scheduling PUCCH to carry dropped HARQ-ACK codebook.*

***Proposal 10:*** *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 11:*** *Determine the type1 HARQ-ACK codebook based on sub-slot with the following procedure:*

* *Divide the PDSCH TDRA in a slot into different SLIV groups (already supported in Rel-15/16);*
* *Associate a SLIV group with a sub-slot according to the latest end symbol of the PDSCHs in the SLIV group;*
* *Generate HARQ-ACK information for each SLIV group in each sub-slot and concatenate the HARQ-ACK information to form type1 HARQ-ACK codebook.*

 ***Proposal 12:*** *Dynamic PUCCH carrier switching should be supported in HARQ-ACK enhancement in Rel-17 URLLC.*

### R1-2100181 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO

***Proposal 1: Subslot-based type-1 HARQ-ACK codebook should be supported in Rel-17.***

***Proposal 2: If subslot- based type-1 HARQ-ACK codebook is supported, to determine the occasions for candidate PDSCH receptions, the following limitation should be considered:***

* ***For a given subslot, if the last symbols of the PDSCH time resource derived by a TDRA row r is not in the subslot, row r is removed from the cardinality of TDRA rows.***

***Proposal 3:*** ***Retransmission of cancelled HARQ-ACK should be supported for Rel-17 URLLC.***

***Proposal 4: A DL grant used to indicate a PUCCH resource for UCI retransmission should be supported.***

***Proposal 5: Deferring SPS HARQ-ACK until a next (e.g., first) available PUCCH.***

* ***A set of UL slots is configured to transmit SPS HARQ-ACK, and separated K1 is configured for each UL slot.***
* ***For a given UL slot, the untransmitted HARQ-ACKs of the SPS PDSCHs before the DL slot corresponding to the indicated K1 are deferred to the given UL slot.***
* ***A PUCCH resource within the slot is determined based on Rel-16 mechanism.***

***Proposal 6: For a HARQ-ACK codebook only including HARQ-ACK corresponding to the SPS configurations with NACK skipping, if all of the information is NACK, UE can skip the HARQ-ACK codebook.***

***Proposal 7: The following two methods for SPS HARQ-ACK compression should be supported:***

* ***The HARQ-ACK codebook for SPS PDSCHs is determined based on the HARQ processes of the multiple SPS PDSCH resources associated with the same PUCCH.***
* ***Multiple SPS*** ***configurations are configured to share one HARQ-ACK bit.***



Figure 3: SPS HARQ-ACK codebook determined based on the HARQ processes



Figure 4: Multiple SPS PDSCH sources share one HARQ-ACK bit in SPS HARQ-ACK codebook

***Proposal 8: The HARQ-ACK skipping/disabling is higher-layer configured per SPS configuration.***

* **The payload size of *Type*-1 HARQ-ACK codebook including HARQ-ACK corresponding to a DCI for SPS release or dynamic PDSCH is not changed.**

### R1-2100226 UE feedback enhancements for HARQ-ACK Huawei, BUPT, China Southern Power Grid, HiSilicon

***Proposal 1*：*Deferring HARQ-ACK until the first available PUCCH resource should be supported to avoid SPS HARQ-ACK dropping for TDD.***

* ***The first available PUCCH resource can be either the PUCCH resource configured for SPS PDSCH only HARQ-ACK (i.e. PUCCH resources configured in sps-PUCCH-AN-List-r16) or the PUCCH resource for dynamic PDSCH HARQ-ACK (i.e. PUCCH resources configured in PUCCH-ResourceSet), depending on which one is the first to be available.***
* ***The time difference between the slot with the end of the SPS PDSCH and the slot with the first available PUCCH resource should be one of the k1 values in the configured K1 set.***

***Proposal 2：Sub-slot based type 1 HARQ-ACK codebook construction should be supported in Rel-17.***

***Proposal 3：PUCCH repetitions over sub-slots should be supported in Rel-17, and dynamic indication of the number of repetitions should be supported.***

***Observation 1: Requiring the UE to always send HARQ feedback for all candidate PDSCHs can result in large overhead and unnecessary UL interference, when multiple DL SPS configurations with low periodicity are configured.***

***Proposal 4：ACK skipping and/or NACK skipping should be supported for DL SPS in Rel-17.***

***Proposal 5：ACK skipping or NACK skipping is performed when the corresponding PUCCH only carries ACKs or NACKs of SPS PDSCH(s), respectively.***

***Proposal 6：Dynamic PUCCH carrier switching could be considered for TDD carriers in Rel-17.***

***Observation 2: If the gNB configures up to two code words that one DCI may schedule, the high priority HARQ-ACK codebook construction based on two code words may increase its size unnecessarily.***

***Proposal 7: Regardless of the configured maximum number of code words, HARQ-ACK codebook construction based on only one code word could be considered for HARQ-ACK codebook with high priority in Rel-17.***

***Proposal 8：Retransmission of cancelled HARQ is not necessary in Rel-17.***

### R1-2100268 HARQ-ACK Enhancements for IIoT/URLLC Ericsson

In the previous sections we made the following observations:

**Observation 1 In the proposed deferring procedure, once the next available slot/sub-slot to use for the deferred SPS HARQ-ACK is determined, the SPS HARQ-ACK can be transmitted in that slot/sub-slot without deferring further.**

**Observation 2 In the proposed deferring procedures, the existing procedures for HARQ-ACK codebook construction is used for construction of the deferred SPS HARQ-ACK.**

**Observation 3 In the proposed deferring procedures, the existing multiplexing rule for multiplexing the deferred SPS HARQ-ACK with other HARQ-ACK bits in the same slot/sub-slot is used.**

**Observation 4 In the proposed deferring procedures, if the deferred HARQ-ACK bit is multiplexed with only HARQ-ACK bits in response to one or more SPS receptions and the UE is provided SPS-PUCCH-AN-List-r16, then the UE determines a PUCCH resource to use for the multiplexed HARQ-ACK bits from sps-PUCCH-AN-ResourceID as defined in the current specification.**

**Observation 5 When SPS occasions are over-provisioned to minimize the alignment delay to the actual transmission, there can be many unnecessary UE feedback transmission (NACK) corresponding to unused SPS occasions with no actual SPS PDSCH transmitted.**

**Observation 6 There is no need to support HARQ-ACK skipping for other multiplexing cases, e.g., multiplexing of HARQ-ACK bits of skipped SPS PDSCH and non-skipped PDSCHs.**

**Observation 7 There is no need for UE to have an independent step to identify the ‘skipped’ SPS PDSCH.**

**Observation 8 The existing PUCCH repetition framework is restrictive as it is only enabled by semi-static configuration and the configuration is tied to PUCCH format.**

**Observation 9 Target BLER of PDSCH transmission depends on use case requirements where different scheduling strategies may be performed considering spectral efficiency. When PDSCH is not always transmitted with extremely low BLER, the benefit of skipping SPS HARQ-ACK with only ACK bits becomes less clear.**

**Observation 10 Large specification impact is expected from dynamic PUCCH carrier switching whereas latency benefit is unclear as it heavily depends on TDD pattern of the carriers.**

**Observation 11 It is sufficient to have semi-static configuration of the PUCCH cell other than PCell to use for HARQ-ACK feedback.**

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

**Proposal 1 Adopt the following procedures when deferring DL SPS only HARQ-ACK is enabled:**

**Proposal 2 SFI is not considered to cause SPS HARQ-ACK deferring.**

**• Note: If the UE detects SFI which turns flexible to DL symbols, causing PUCCH carrying SPS HARQ-ACK to collide with invalid symbols, then the UE simply follows the already existing behavior.**

**Proposal 3 Allow configuration of additional “invalid symbols or slot/sub-slots” which are considered invalid and cannot be used for the deferred SPS HARQ-ACK.**

**Proposal 4 If needed, the maximum number of slots for which SPS HARQ-ACK deferring is allowed is limited by the maximum K1 value in the set of configured slot timing values.**

**Proposal 5 Support HARQ-ACK feedback skipping for a codebook with only DL-SPS HARQ ACK feedback when all HARQ-ACK bits in the codebook are NACK.**

**Proposal 6 Do not support dynamic indication of skipped SPS PDSCH occasions.**

**Proposal 7 Support sub-slot based PUCCH repetition where PUCCH repetition is performed across multiple sub-slots and each repetition uses the same resource (i.e., same starting symbol within a sub-slot, duration, and number of PRBs).**

**Proposal 8 Support having a repetition factor for PUCCH repetition as part of the configuration of PUCCH resources.**

**Proposal 9 PUCCH repetition is supported for all PUCCH formats.**

**Proposal 10 If the scenario of cancelled HARQ-ACK is still present in Rel-17, support HARQ feedback based on Type-3 HARQ-ACK codebook to recover the cancelled HARQ-ACK.**

**Proposal 11 Support Type-3 HARQ-ACK codebook with priority indication in the triggering DCI.**

**Proposal 12 Support Type-3 HARQ-ACK codebook where only A/N of “activated CCs” are included in the codebook instead of all “configured CCs”.**

**• Study other methods for size reduction for Type 3 HARQ-CB**

**Proposal 13 Do not support SPS HARQ payload size reduction.**

**Proposal 14 Support Type-1 HARQ-ACK codebook for sub-slot in Rel17.**

**Proposal 15 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 2μDL-μUL is changed to 2μDL-μUL/N, where N is the number of sub-slots in an UL slot.**

**Proposal 16 Once Type-1 codebook for sub-slot is supported, further optimization to reduce Type-1 codebook size can be considered.**

**Proposal 17 Do not support dynamic PUCCH carrier switching.**

**Proposal 18 Support a configuration of pucch-Cell on PCell to indicate another serving cell within the same cell group to use for PUCCH.**

### R1-2100302 UE feedback enhancements for HARQ-ACK CAICT

***Observation 1: Always exempting semi-static F symbols from being valid symbols is detrimental from the latency performance point of view for URLLC.***

***Proposal 1: gNB configures whether UL symbols indicated by SFI could be valid symbols when decide available PUCCH or not.***

***Proposal 2: To decide the number of contiguous 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 3: Semi-static configured PUCCH transmission according to SPS-PUCCH-AN-List-r16 or multi-CSI-PUCCH-ResourceList could be used as available PUCCH.***

***Proposal 4: gNB configures whether PUCCH transmission scheduled for dynamic HARQ-ACK could be used as available PUCCH or not.***

***Proposal 5: 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.***

***Observation 2: The current triggering procedure is flexible.***

***Proposal 6: Optimize one-shot HARQ CB triggering if CB optimization is supported.***

***Proposal 7: SPS HARQ-ACK skipping is used when one PUCCH only includes SPS HARQ-ACK for skipped SPS PDSCH and all the HARQ-ACKs are NACK. If twice blind detecting could be supported, SPS HARQ-ACK skipping could be used in one PUCCH which SPS HARQ-ACK skipping is multiplexed with other UCI and all the SPS HARQ-ACKs are NACK.***

### R1-2100376 UE feedback enhancements for HARQ-ACK CATT

***Proposal 1: Whether SPS HARQ-ACK should be delayed 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: FFS which PUCCH resource should be used to determine the next available PUCCH resource when there is initial SPS HARQ-ACK in a slot with the following options:***

* ***Option 1: The PUCCH resource used for delayed SPS HARQ-ACK only is used to determine the next available PUCCH resource***
* ***Option 2: The PUCCH resource used for both initial and all delayed SPS HARQ-ACK is used to determine the next available PUCCH resource***

***Proposal 3: If PUCCH for SPS HARQ-ACK collides with semi-static DL symbol(s) or SSB symbols, the SPS HARQ-ACK feedback can be delayed to an earliest subsequent slot/sub-slot with a PUCCH symbol allocation for SPS only feedback within the slot/sub-slot which does not collide with semi-static DL symbol(s) or SSB symbols.***

***Proposal 4: SPS HARQ-ACK can only be delayed to a slot/sub-slot included in configured K1 set, otherwise the SPS HARQ-ACK should be dropped.***

***Proposal 5: One-shot codebook type can be used for SPS HARQ-ACK re-transmission, and one-shot codebook can be configured to include HARQ-ACK for HARQ processes of SPS PDSCHs only.***

***Proposal 6: Enhance sub-slot based Type-1 HARQ-ACK codebook to reduce redundant HARQ-ACK bit(s) and to include all the PDSCH occasions.***

***Proposal 7: Extending SLIVs in a serving cell for Type-1 HARQ-ACK codebook should be enhanced by considering the SLIVs in slot(s) configured with DCI format 1\_2 monitoring only and considering PDCCH monitoring occasions in that slot only in case repetitions is not configured for the serving cell.***



Figure 5: Issue of extending reference SLIV for Type-1 codebook



Figure 6: Issue of extending reference SLIV for Type-1 codebook

***Proposal 8: Dynamic indication of skipped SPS PDSCH occasions is not supported in Rel-17.***

***Proposal 9: Disable HARQ-ACK feedback for one or multiple SPS configurations can be considered for SPS HARQ payload size reduction.***

***Proposal 10: Configuring the number of repetition times for each PUCCH resource can be considered in Rel-17.***

### R1-2100436 HARQ-ACK enahncements for Rel-17 URLLC vivo

***Proposal 1: 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 SPS HARQ-ACK transmissions in Rel-15/16.***

***Proposal 2:*** ***It should be discussed how to determine an available PUCCH resource in time domain, and the following options could be considered:***

* ***Option 1: Based only on RRC configurations, and considering only semi-static UL symbol(s).***
* ***Option 2: Based only on RRC configurations, and considering both semi-static UL symbol(s) and semi-static flexible symbol(s).***
* ***Option 3: Based on both RRC configuration and L1 signalling, and reusing Rel-15/16 rules to validate a transmission corresponding to a PUCCH resource.***

***Proposal 3: It should be clarified whether the case is regarded as out-of-order or not when the HARQ-ACK feedback corresponding to dynamically scheduled PDSCH(s) starting later than the SPS PDSCH(s) is transmitted before the determined available PUCCH resource conveying the deferred SPS HARQ-ACK.***

***Proposal 4: To determine an available PUCCH resource for conveying the deferred SPS HARQ-ACK, consider only the RRC configurations, and both semi-static UL symbol(s) and semi-static flexible symbol(s) can be used for the available PUCCH resource.***

***Proposal 5:*** ***It should be determined if there is any limitation for feedback offset applied to deferred SPS HARQ-ACK, and regarding the limitation, following options could be considered:***

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

***Proposal 6:*** ***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 feedback offset for deferred SPS HARQ-ACK.***

***Proposal 7:*** ***It should be discussed to control or reduce the codebook size when a type-3 codebook is triggered to retrieve deferred SPS HARQ-ACK.***

***Proposal 8:*** ***The two options to address the issue of SPS HARQ-ACK dropping for TDD systems can complement each other, and both can be supported.***

***Proposal 9:*** ***NACK skipping for SPS PDSCH should mainly focus on the case of HARQ-ACK codebooks containing only SPS HARQ-ACK.***

***Proposal 10:*** ***At least support NACK skipping, which can be applied for both skipped SPS PDSCH and non-skipped SPS PDSCH without explicit identification.***

***Proposal 11:*** ***Unified method(s) is supported for retransmission of cancelled HARQ-ACK for low priority and high priority.***

***Proposal 12:*** ***HARQ-ACK retransmission mechanisms introduced in NR-U Rel-16 are considered as a starting point, and there is no need to introduce additional ones.***

***Proposal 13:*** ***Type-3 codebook and/or enhanced type-2 codebook can be clarified and enhanced further as required.***

***Proposal 14:*** ***Type-3 codebook is prioritized for clarifications and potential enhancements.***

***Proposal 15:*** ***Do not support PUCCH carrier switching for HARQ-ACK for URLLC Rel-17 unless practical deployment scenarios are identified.***

### R1-2100574 On UE feedback enhancements for HARQ-ACK MediaTek Inc.

***Observation 1: PUCCH alignment adds to the latency especially for TDD operation with DL-heavy patterns hence compromising both the latency and the reliability.***

***Observation 2: The sub-6 TDD bands are widely deployed for 5G-NR. They suffer however from large latency, penalizing the URLLC deployment in these bands.***

***Observation 3: Use of mini-slots scheduling and UE processing time capability #2 don’t deliver any substantial latency advantage for TDD patterns with large UL/DL periodicity.***

***Observation 4: The UL/DL TDD pattern is the bottleneck for the URLLC latency for deployment on sub-6 TDD bands.***

***Observation 5: Dynamic cross-carrier PUCCH allows for up to 30% latency reduction.***

***Observation 6: Dynamic cross-carrier PUCCH doubles the network capacity and reduces the resource utilization compared to the Carrier Aggregation baseline operation.***

***Observation 7: Receive diversity is essential for enhancing the reliability of PUCCH.***

***Observation 8: The required SNR for achieving the target NACK-to-ACK error rate is generally higher than the required SNR for achieving the target missed ACK rate.***

***Observation 9: The difference between the required SNR for achieving the target missed ACK and NACK-to-ACK error rates depends on the system setting (e.g. number of PRBs and number of receive antennas).***

1. ***Support dynamic cross-carrier PUCCH for Carrier Aggregation.***
2. ***All DCIs pointing to the same PUCCH carry the same PUCCH carrier index, hence no overriding and no risk if one DCI is missed.***
3. ***Selection between Option-1 and Option-2 for the PUCCH configuration:***
* ***Option 1: A PUCCH configuration per PUCCH carrier.***
* ***Option 2: Define two levels of PUCCH configuration, “per PUCCH group” and “per PUCCH carrier”.***
1. ***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.***
2. ***Support different PUCCH transmission power levels depending on whether ACK or NACK is transmitted.***
3. ***Don’t proceed with the SPS HARQ skipping for “skipped” SPS PDSCH study in RAN1.***
4. ***Don’t proceed with the PUCCH repetition enhancement study in RAN1.***
5. ***Support retransmission of cancelled low priority and high priority HARQ.***
6. ***Don’t proceed with SPS HARQ payload size reduction study in RAN1***
7. ***Don’t proceed with sub-slot based type 1 HARQ-ACK codebook for URLLC in RAN1 Rel-17***

### R1-2100649 UE HARQ feedback enhancements for URLLC/IIoT Intel Corporation

**Proposal 1**

* *To address the issue of SPS HARQ-ACK dropping for TDD systems, support both Option 1 and Option 2 defined in RAN1#103-e.*

**Proposal 2**

* *For Option 1, addressing the issue of SPS HARQ-ACK dropping for TDD systems,*
	+ *Support configuration of additional PUCCH resource(s) to a UE for searching for the next available PUCCH resource, with possibly different PUCCH format, start symbol, length symbol, K1 value for DL SPS HARQ-ACK:*
		- *The additional PUCCH resource can be used whenever the original PUCCH resource could not be mapped due to collision with DL symbols or flexible symbols if SFI is not configured, FFS case if SFI is configured.*

**Proposal 3**

* *For Option 2, addressing the issue of SPS HARQ-ACK dropping for TDD systems,*
	+ *Support configuring Type 3 CB to carry only DL SPS HARQ-ACK information on a given carrier;*
	+ *Support grouping DL SPS HARQ-ACK processes on a carrier to be multiplexed in a given Type 3 CB.*

**Proposal 4**

* *Support enhanced PUCCH repetition mechanism resulting in repetitions within a slot or across slots, each repetition possibly having different starting symbol and duration.*
	+ *FFS details*

**Proposal 5**

* *Support enhanced PUCCH repetition mechanism with dynamic indication of the total PUCCH duration, i.e. dynamic indication of number of repetitions.*
	+ *PUCCH resource ID in this case points to the number of PUCCH repetitions associated with the triggered PUCCH format.*

**Observation 1**

* ***Feasibility and benefits of SPS HARQ skipping for skipped SPS PDSCH based on dynamic indication of skipped SPS PDSCH occasions (Alt. 3) in case of realistic system operation conditions are not proven.***

**Observation 2**

* ***‘NACK skipping’ for (skipped) SPS PDSCH under the assumption of no detection of skipped PDSCH is beneficial in a limited number of cases, but can be considered as a*** *dropping of a PUCCH containing only SPS HARQ-ACK with only NACKs.*
* ***‘NACK skipping’ for (skipped) SPS PDSCH under the assumption of no detection of skipped PDSCH should be considered against other options classified as*** *SPS HARQ payload size reduction.*

**Proposal 6**

* *For SPS HARQ payload size reduction, support (Alt. 3) grouping of SPS PDSCH occasions which are bundled into a single HARQ-ACK bit.*
	+ *Bundling can be performed based on explicit configuration or based on HARQ process IDs.*

### R1-2100728 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: Support deferring HARQ-ACK until a next (e.g., first) available PUCCH to address the issue of SPS HARQ-ACK dropping for TDD systems.**

* **FFS: Details including the definition of a next (e.g., first) available PUCCH, CB construction / multiplexing**

**Proposal 2.2: To address the issue of SPS HARQ-ACK dropping for TDD systems, the details and enhancements related to “Dynamic triggering of a one-shot / Type-3 CB type of re-transmission” (Option 2) are jointly discussed with “re-transmission of canceled HARQ-ACK” topic.**

**Proposal 2.3: For the deferring of SPS HARQ-ACK until a next available PUCCH, the next available PUCCH is defined as the next applicable PUCCH resource having no overlap at least with semi-static DL or SSB symbols.**

* **FFS: whether SFI is taken into account (Nokia preference) or having no overlap with semi-static flexible symbols**

***Observation 2.1: Selecting a PUCCH resource for deferred SPS HARQ-ACK from the PUCCH resource pool configured for dynamic PDSCH may require large specification effort due to the large amount of PUCCH resources to choose from.***

**Proposal 2.4: For the deferring of SPS HARQ-ACK until a next available PUCCH, the PUCCH resource in case of SPS HARQ-ACK only is selected among the PUCCH resources configured for HARQ-ACK of SPS PDSCH.**

* **FFS: whether to provide an additional set of candidate PUCCH resources to the UE in addition to those in *sps-PUCCH-AN-List-r16* to increase flexibility and reduce the HARQ-ACK latency.**

***Observation 2.2: For the case where the HARQ-ACK codebook only contains HARQ-ACK bits from multiple (deferred and/or non-deferred) SPS PDSCHs (i.e. no HARQ-ACK bits of PDSCH scheduled by a DCI), existing SPS-only codebook construction mechanism/pseudocode in TS 38.213 Clause 9.1.2 can be used.***

***Observation 2.3: For Type-2 HARQ-ACK codebook construction with a mix of SPS and dynamic PDSCH HARQ-ACK, SPS HARQ-ACK bits can be appended to the end of the codebook and sorted in the same way as for the SPS-only case. No significant changes are foreseen to support the deferring operation.***

**Proposal 2.5: In case the deferred SPS HARQ-ACK is multiplexed with dynamic PDSCH HARQ-ACK on a Type-1 codebook, one bit per postponed SPS PDSCH HARQ-ACK is appended to the Type-1 codebook in case the PDSCH to HARQ-ACK timing is not covered by the configured K1 set.**

The discussions **in Sec. 3 on SPS HARQ skipping for ‘skipped’ SPS PDSCH** can be summarized in the following related observations and proposals:

**Proposal 3.1: Support NACK skipping for SPS PDSCH**

* **NACK skipping is separately configurable for each SPS configuration.**
* **The skipping procedure is to be limited to the single case of only SPS NACK feedback is to be reported on the PUCCH. For all other cases, such as a mix of SPS ACK and NACK (or HARQ ACK for dynamic PDSCH), or other type of UCI to be mapped to PUCCH/PUSCH or if SPS NACK for skipped SPS PDSCH is the only UCI to be mapped to PUSCH, the UE should not skip the HARQ transmission / mapping.**

***Observation 3.1: Supporting dynamic indication of skipped SPS PDSCH occasions may lead to wrong CB size assumption, create unwanted PUCCH collisions and loss of soft-channel bits.***

***Observation 3.2: In current Release 16, the timeline for overwriting a SPS PDSCH with dynamic PDSCH is at least 14 OFDM symbols as the UE needs some time to prepare for the PDSCH reception. Dynamic indication of skipped/cancelled SPS PDSCH occasions may possible be subject to similar timeline.***

**Proposal 3.2: Do not support dynamic indication of skipped SPS PDSCH occasions.**

The discussions **in Sec. 4 on enhancements for SPS HARQ ACK payload reduction** can be summarized in the following related observations and proposals:

**Proposal 4.1: For SPS PDSCH HARQ-ACK feedback reduction, consider the following:**

* **Support SPS HARQ disabling/skipping for certain SPS configurations (Alt. 4)**
	+ **The HARQ-ACK information is mapped only in case HARQ-ACK of a PDSCH scheduled by a DCI is mapped and Type-1 CB operation. Otherwise, the HARQ-ACK information is not mapped / skipped.**
* **Continue the discussion on SPS HARQ-ACK bundling/compression (Alt. 3)**
	+ **Note: There should not be any restrictions regarding the number of SPS PDSCHs that can be scheduled to the UE in each SPS bundle**
* **Do not support ACK skipping (Alt. 1)**

The discussions **in Sec. 5 on PUCCH repetition enhancements** can be summarized in the following related observations and proposals:

***Observation 5.1: Based on our understanding, the RAN plenary decision implies that Alt. 2 (Back-to-back PUCCH repetition – i.e. ‘PUSCH Rep. B Type’, repetition within a subslot) and Alt. 3 (Repetitions to support different starting point & duration based on PUCCH configuration) are not considered as part of this WI any longer.***

**Proposal 5.1: Support sub-slot based PUCCH repetition (same start / duration / PUCCH resource in each subslot, one repetition per subslot) at least for HARQ-ACK.**

* **FFS: per repetition PUCCH dropping rules concerning overlapping with DG PUSCH**
* **FFS: support of sub-slot based PUCCH repetition to be also applicable for SR and/or CSI**
* **FFS: enabling multiplexing of different UCI types within a PUCCH repetition bundle**

The discussions **in Sec. 6 on retransmissions of dropped HARQ-ACK** can be summarized in the following related observations and proposals:

***Observation 6.1: In case that HARQ ACK multiplexed on PUSCH is dropped, triggering retransmission of dropped HARQ-ACK via DCI scheduling UL grant and/or via semi-static configuration at least for CG PUSCH could decrease the downlink control overhead.***

**Proposal 6.1: e-Type 2 CB enhancements for URLLC are not specified in Rel-16.**

**Proposal 6.2: RAN 1 to specify Type 3 codebook enhancements for URLLC, including**

* **Limiting the Type 3 CB to only a subset of the HARQ ACK processes to the codebook. A method for further studies is indicating in the triggering DCI which preconfigured set of processes is included.**
* **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 6.3: Study triggering the retransmission of dropped HARQ-ACK on PUSCH via DCI scheduling the PUSCH and via semi-static configuration (at least for CG PUSCH).**

The discussions **in Sec. 7 on Type 1 HARQ ACK Codebook enhancements** which summarize only on additional possible enhancements can be summarized in the following related observations and proposals:

**Proposal 7.1: Focus the discussions on the Type-1 CB for sub-slot PUCCH on the properties of the codebook and not necessarily the detailed implementation steps (which could be left to the 38.213 editor).**

**Proposal 7.2: Support Type-1 CB for sub-slot PUCCH based on the following codebook properties:**

* **The HARQ-ACK multiplexing window is defined based on the HARQ-ACK timing set K1 and sub-slot length.**
	+ **The applicable K1 set considering the applicable DCI formats for the PUCCH configuration based on Sec. 9.1.1.1 of TS 38.213 is reused.**
* **Definition of the union set of TDRA entries: A PDSCH TDRA is associated with an UL / PUCCH sub-slot if the end of the PDSCH overlaps with the UL sub-slot.**
* **The pruning is performed per PUCCH sub-slot based on the TDD configuration (as in Rel-15, but per sub-slot)**
* **FFS: additional codebook size optimizations**

**Proposal 7.3: To reduce the Type-1 HARQ-ACK codebook size, the gNB should be able to configure the UE with a special “feedback” TDRA tables used for Type-1 HARQ-ACK codebook construction. This “feedback” TDRA table is used in the Type-1 HARQ-ACK CB construction pruning process and maps the possible DL assignment for PDSCH (e.g. SPS) into the entries of the “feedback” TDRA table.**



Figure 7.1. Example TDRA table with 6 rows.



Figure 7.2. HARQ-ACK bit position after R15 pruning. For this we need a codebook of 4 bits.

If a separate TDRA table is configured (let’s call it Feedback TDRA (F-TDRA) table), such as the one illustrated in Figure 7.3, then the resulting HARQ-ACK bit number to each entry in the example TDRA table in Figure 7.1 is illustrated in Figure 7.4.



Figure 7.3. Example of a F-TDRA table.



Figure 7.4. HARQ-ACK bit position after pruning of the TDRA table of Figure 7.1 into the example F-TDRA table of Figure 7.3. With the configured example F-TDRA, the codebook size is reduced to 2 bits.

The discussions **in Sec. 8 on dynamic PUCCH carrier switching** can be summarized in the following related observations and proposals:

**Proposal 8.1: To decide if PUCCH carrier switching will be specified, focus the further complexity versus gain analysis on dynamic indication of PUCCH carrier switching of Alt. 1.**

### R1-2100803 Discussion on physical Layer feedback enhancements Spreadtrum Communications

***Proposal 1. Semi-static flexible symbol can be considered for available PUCCH transmission.***

***Proposal 2. For all the available PUCCH resources in the slot/sub-slot, a first PUCCH resource should be selected, e.g., the one with earliest starting/ending symbol.***

***Proposal 3. NACK skipping is supported, and it can be applied by both skipped and non-skipped SPS PDSCH.***

***Proposal 4. NACK skipping scheme can be configured by RRC signalling for all configured SPSs.***

***Proposal 5. ACK skipping scheme can be considered for SPS HARQ payload size reduction of non-skipped SPS PDSCH.***

***Proposal 6: Format 0 and format 2 can be supported sub-slot based PUCCH repetition transmission.***

***Proposal 7: Support dynamic indication of repetition number of PUCCH transmission, existing bit filed can be used to jointly indicate the PUCCH repetition number, such as PRI field.***

***Proposal 8. Support sub-slot based type1 HARQ-ACK codebook in Rel-17 URLLC to further enhancement UCI reliability.***

***Proposal 9. The codebook size should be constrained for sub-slot based type 1 codebook.***

***Proposal 10. Similar as Rel-16 type 1 codebook, the union set of row indexed of TDRAs are used to determine the PDSCH occasions, including for DCI formats the UE is configured to monitor PDCCH and reference of SLIV if it is configured.***

### R1-2100855 Considerations on HARQ-ACK enhancements for URLLC Sony

**Observation 1: The first available PUCCH may be overloaded due to accumulation of dropped SPS HARQ-ACKs.**

**Observation 2: Using DCI to trigger for Type-3 CB for retransmission of dropped SPS HARQ-ACK may lead to PDCCH blocking and latency in providing the HARQ-ACK retransmission.**

**Observation 3: If the HARQ-ACK for a group of SPS’s are bundled using an “OR” operator then the gNB would not be able to determine when there is more than one ACKed PDSCH if the gNB sends more than 1 PDSCH to the UE and would be unable to issue a PDSCH retransmission.**

**Observation 4: 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 5: The 2 levels L1 priority introduced in Rel-16 for UL intra-UE prioritization is not sufficient to handle inter sub-slot PUCCH repetitive collisions.**

**Observation 6: The 1st PUCCH repetition has the highest importance compared to subsequent repetitions of the same PUCCH.**

We therefore propose the following:

**Proposal 1: The first available PUCCH to carry retransmission of dropped SPS HARQ-ACK can be a PUCCH carrying HARQ-ACK for other SPS’s or DG-PDSCHs.**

**Proposal 2: Up to *NHARQ* SPS HARQ-ACKs that are dropped due to collision with DL symbols or invalid symbols in TDD can be retransmitted by multiplexing into the first available PUCCH resource. Value of *NHARQ* is FFS.**

**Proposal 3: Consider triggering for PUCCH to carry Type-3 CB for the dropped SPS HARQ-ACK retransmission without using DCI but instead the Type-3 CB is triggered when *NDrop* SPS HARQ-ACKs are dropped.**

**Proposal 4: If SPS HARQ skipping is supported, consider using MAC CE in a transmitted SPS PDSCH to indicate dynamically which SPSs are skipped.**

**Proposal 5: If reduction of SPS HARQ-ACK overhead is required, use HARQ bundling where the UE feeds back the number of ACKs observed in a defined group of SPS’s.**

* **PUCCH Format 0 with 8 cyclic shifts can be used to indicate up to 7 ACKs.**

**Proposal 6: 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.**

**Proposal 7: Consider retransmission of cancelled Low L1 priority and High L1 priority HARQ-ACKs.**

**Proposal 8: Consider using e-Type 2 and/or Type 3 HARQ-ACK codebooks as a starting point in designing the mechanism to handle retransmission of cancelled HARQ-ACKs.**

**Proposal 9: Consider handling of retransmissions of cancelled HARQ-ACK with one L1 priority and/or codebook type in another HARQ-ACK codebook of different L1 priority and/or different codebook type.**

### R1-2100880 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics

Proposal 1: Consider to shift the HARQ-ACK feedback for SPS PDSCH from invalid PUCCH resource to next available PUCCH resource.

Proposal 2: For SPS PUCCH occasion overlapping semi-static DL symbol, postpone HARQ-ACK transmission to next SPS PUCCH occasion of corresponding SPS configuration.

* FFS: whether to use SPS PUCCH occasion for different SPS configuration.

Proposal 3: When delaying HARQ-ACK transmission for SPS PDSCH reception is supported, the end of delayed HARQ-ACK transmission should be no later than,

* The starting symbol of upcoming PDSCH occasion corresponding to same HARQ process ID, and
* The ending symbol of the PUCCH transmission carrying HARQ-ACK of other PDSCH reception received after the SPS PDSCH reception.

Proposal 4: 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 5: 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 6: Consider to support NACK only HARQ-ACK feedback based on PUCCH resource request in order for reducing PUCCH overhead.

Proposal 7: Consider to support sub-slot based PUCCH repetition with following aspects.

* Take Rel-15/16 slot-based PUCCH repetition structure as a baseline

Proposal 8: Support type-3 HARQ-ACK codebook for re-transmission of cancelled HARQ-ACK with reduced HARQ-ACK payload size if necessary.

Proposal 9: it is necessary to remove unusable candidate PDSCH reception in type-1 HARQ-ACK codebook from the following cases:

* A K1 value is corresponding to only one DCI format
* A TDRA entry is corresponding to only one DCI format

### R1-2100911 Discussion on UE feedback enhancements for HARQ-ACK China Telecom

***Proposal 1: To avoid SPS HARQ-ACK dropping for TDD systems, support HARQ-ACK deferring until a next (e.g., first) available PUCCH as a prior option.***

***Proposal 2: SPS HARQ-ACK is deferred until a next (e.g., first) available PUCCH only when it collides with semi-statically configured DL symbol or SSB symbol.***

***Proposal 3: The available PUCCH for SPS HARQ-ACK deferring is consist of at least semi-static uplink symbol(s).***

***Proposal 4: Reuse the Rel-15/Rel-16 mechanism for SPS HARQ-ACK feedback to multiplex the deferred SPS HARQ-ACK with other HARQ-ACK and determine the PUCCH resource.***

***Proposal 5: When a PUCCH HARQ-ACK codebook only contains HARQ-ACK for SPS PDSCH, and all of the HARQ-ACK for these SPS PDSCH are going to be NACK, the UE does not send the PUCCH.***

***Proposal 6: Support sub-slot based PUCCH repetition as well as PUCCH format 0/2 repetition in Rel-17. For PUCCH repetition in multiple sub-slots, the same PUCCH resource (starting symbol, duration and PRB number) is used in each sub-slot.***

***Proposal 7: Retransmission of cancelled HARQ should be studied with low priority as the use case depends on the outcome of intra UE multiplexing discussion.***

***Proposal 8: If PUCCH carrier switching is supported in Rel-17, it is switched based on static predefined rules for both dynamically scheduled PDSCH and SPS PDSCH HARQ-ACK feedback.***

### R1-2100920 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.

**Observation 1: If the determination of this available PUCCH is performed by UE, it may be misalignment between the base station and UE.**

**Proposal 1: 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 2: Flexible symbol(s) should be used as available PUCCH resource for transmitting the deferred HARQ-ACK feedback.**

**Proposal 3: The total number of deferred HARQ-ACK bits needs to be limited**

**Proposal 4: The time interval between the deferred HARQ-ACK feedback and receiving the corresponding SPS PDSCH should not exceed the maximum value of k1.**

**Proposal 5: Candidate k1 value(s) should be provided for UE to determine the available PUCCH for transmitting deferred HARQ-ACK feedback.**

**Observation 2: Reuse Type-3 HARQ-ACK codebook in Rel-16 to retransmit the dropped SPS HARQ-ACK feedback would lead to redundancy overhead.**

**Proposal 6: The enhancement for reducing the Type-3 HARQ-ACK codebook size should be studied, e.g. only transmitting the dropped HARQ-ACK processes or SPS HARQ processes.**

**Proposal 7: Using one-shot HARQ-ACK codebook for retransmission of dropped SPS HARQ-ACK feedback and cancelled HARQ-ACK feedback should be discussed separately.**

**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 especially for jitter handling.**

### R1-2100948 UE feedback enhancements for HARQ-ACK NEC

**Proposal 1:**

* *Semi-static HARQ-ACK codebook for sub-slot based HARQ-ACK feedback procedure should be supported in Rel-17.*

**Proposal 2:**

* *When DL and UL are configured with same numerology, the sub-slot based semi-static HARQ-ACK codebook can be determined based on following three-steps:*
	+ *Step 1: Determine the HARQ-ACK multiplexing window based on the HARQ-ACK timing set and sub-slot length.*
	+ *Step 2: Split the TDRA table into N sub-tables based on the sub-slot length and PDSCH-to UL sub-slot association. N is the number of sub-slots within a slot.*
	+ *Step 3: Do pruning based on TDD configuration and sub-table per sub-slot similar as Rel-15.*
* *When DL and UL are configured with different numerologies, further study the sub-slot based semi-static HARQ-ACK codebook determination.*

**Proposal 3:**

* *In case PUCCH resource for SPS HARQ-ACK is not available due to collision with DL symbol or flexible symbol, support deferring HARQ-ACK for SPS PDSCH until a next available PUCCH*
	+ *The next available PUCCH is the earliest PUCCH resource not overlapped with invalid symbol among next PUCCH resources configured for SPS PDSCH and indicated for dynamic scheduled PDSCH.*
		- *If the number of HARQ-ACK bits carried in a configured PUCCH resource exceeds the value M, then the PUCCH resource is not valid for the delayed HARQ-ACK.*
	+ *Support multiplexing the delayed HARQ-ACK for SPS PDSCH and HARQ-ACK for dynamically scheduled PDSCH(s) on a HARQ-ACK codebook.*
		- *Append the delayed HARQ-ACK bits for SPS PDSCH after the HARQ-ACK codebook for dynamically scheduled PDSCH(s).*

**Proposal 4:**

* *Support dynamic triggering of a one-shot / Type-3 CB type of HARQ-ACK re-transmission for SPS PDSCH due to collision between PUCCH resource and invalid symbol.*
	+ *Following options can be considered to reduce the Type-3 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 activated 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 activated 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 activated CC(s).*
	+ *FFS the PUCCH resource determination for the triggered Type-3 HARQ-ACK codebook for SPS PDSCH only.*

**Proposal 5:**

* *Support skipping PUCCH transmission if all HARQ-ACK bits in the PUCCH resource for SPS PDSCH only are NACK.*

**Proposal 6：**

* *Further study whether support dynamic indication of skipped SPS PDSCH occasions in Rel-17.*

**Proposal 7：**

* *Support semi-static indication for PUCCH carrier switching for HARQ-ACK in Rel-17.*

**Proposal 8：**

* *Further study the PUCCH power control if PUCCH carrier switching for HARQ-ACK is supported.*

**Proposal 9:**

* *The Type-1 HARQ-ACK codebook ACK/NACK bits will only be present if the corresponding slot or sub-slot has at least one PDCCH transmission, and the reliability of Type-1 HARQ-ACK codebook for URLLC service can be further enhanced by the reuse of DAI counters.*

### R1-2100968 Discussion on UE feedback enhancements for HARQ-ACK Asia Pacific Telecom, FGI

Observation 1 Both a high priority HARQ-ACK codebook and a low priority HARQ-ACK codebook may be cancelled.

Proposal 1 The maximum number of slots that can be deferred for SPS HARQ-ACK is configured per SPS configuration.

Proposal 2 The first available PUCCH resource for a SPS HARQ-ACK is defined as the first PUCCH resource selected from SPS-PUCCH-AN-List in a slot after the original slot indicated by K1 for the SPS HARQ-ACK, based on the payload size of deferred SPS HARQ-ACK and non-deferred SPS HARQ-ACK in the slot, if the symbols conatining the PUCCH resource includes semi-UL symbols in the slot. FFS if the first PUCCH resource includes semi-flexible symbols.

Proposal 3 Study mechanism for retransmission of high priority HARQ-ACK codebook and low priority HARQ-ACK codebook using enhanced Type-2 HARQ-ACK codebook and Type-3 HARQ-ACK codebook as a starting point.

Proposal 4 Support triggering a Type-3 HARQ-ACK codebook by a DCI indicating low priority or indicating high priority.

Proposal 5 Determine whether to support PUCCH carrier switching between different PUCCH cell groups.

Proposal 6 Support dynamic indication (e.g., DCI field) for PUCCH carrier switching for HARQ-ACK.

Proposal 7 Some semi-static rules for PUCCH carrier switching for HARQ-ACK could be considered.

Proposal 8 Consider a configurable indication for selecting between dynamic indication and semi-staic rule as a compromised option.

### R1-2100993 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility

* **Observation 1: In SPS operation for IIoT, delaying HARQ-ACK feedback beyond a certain time may not be useful, since the communication service may be considered unavailable after survival time.**
* **Proposal 1: Define the maximum allowed HARQ-ACK feedback delay for a given SPS PDSCH or a set of consecutive SPS PDSCHs.**
* **Proposal 2: If UE cannot transmit HARQ-ACK information within the configured maximum HARQ-ACK feedback delay, the UE may discard the HARQ-ACK information.**
* **Proposal 3: 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 4: Support one shot HARQ-ACK transmission for all HARQ processes in a CG-PUSCH resource.**
* **Proposal 5: In NR URLLC Rel-17, support skipping of HARQ-ACK feedback (both ACK and NACK) for a consecutive number of instances:**
	+ **Number of consecutive instances for skipping HARQ-ACK can be configured by gNB depending upon of the survival time requirement for the application (this avoids any ambiguity for HARQ-ACK codebook construction)**
* **Observation 2: Configuring a UE with multiple PUCCH carriers and allowing the UE to dynamically switch across the configured PUCCH carriers can provide the UE with more HARQ-ACK transmission opportunities under dynamic TDD operation.**
* **Proposal 6: Support dynamic PUCCH carrier switching, in order to avoid frequent cancellation of HARQ-ACK transmission for SPS PDSCHs with short periodicities.**

### R1-2101013 Discussion on UE feedback enhancements for HARQ-ACK Panasonic Corporation

**Proposal 1: For support avoiding SPS HARQ-ACK dropping for TDD, both Option 1 and Option 2 are supported in Rel.17.**

* **Option 1: Deferring HARQ-ACK until a next (e.g., first) available PUCCH**
* **Option 2: Dynamic triggering of a one-shot / Type 3 CB type of retransmission**

**Proposal 2: For deferring HARQ-ACK until a next available PUCCH (Option 1),**

* **On determining a next available PUCCH, at least semi-static UL symbols that are not SS/PBCH block symbols should be considered.**
* **On PUCCH resource for the next available PUCCH, PUCCH resource for SPS PDSCH (PUCCH resources configured in sps-PUCCH-AN-List-r16) should be considered.**

**Proposal 3: For Dynamic triggering of a one-shot / Type 3 CB type of retransmission (Option 2)**

* **The design should be unified for SPS HARQ dropping for TDD and retransmission of cancelled HARQ-ACK.**
* **Instead of reporting HARQ-ACK for all configured HARQ processes, only transmitting SPS HARQ processes or dropped HARQ processes can be considered.**

**Observation 1: The motivation to considering ‘skipped’ SPS PDSCH should be clarified.**

**Observation 2: In low BLER operation, ACK skipping is more reasonable than NACK skipping.**

**Observation 3: Involving HARQ codebook may not provide gain of HARQ skipping.**

**Proposal 4: ACK skipping for SPS PDSCH is supported for one or two bits HARQ-ACK case.**

**Proposal 5: Sub-slot-based PUCCH repetition is supported in Rel.17.**

**Proposal 6: For sub-slot-based PUCCH repetition, PUCCH formats 0 or 2 should also be applicable for PUCCH repetition.**

**Proposal 7: Dynamic indication of the number of repetitions to be specified in NR coverage enhancement should also be applicable to sub-slot-based PUCCH repetition.**

### R1-2101039 Discussion on UE feedback enhancements for HARQ-ACK CMCC

**Proposal 1: Support defer HARQ-ACK for SPS PDSCH to next (e.g., first) available PUCCH resource in case it collides with downlink symbols configured by TDD-UL-DL-ConfigCommon/Dedicated.**

**Proposal 2: For definition of next available PUCCH resource, the following alternatives can be further studied:**

* **Alt.1: first in time -after the instant of deferred SPS HARQ-ACK, available set of symbols without DL symbol(s) configured by TDD-UL-DL-ConfigCommon or TDD-UL-DL-ConfigDedicated;**
* **Alt.2: periodically configured PUCCH resource/slot, and UE could expect that the configuration of periodic PUCCH resource/slot is always aligned with semi-static UL/DL configuration;**
* **Alt 3: PUCCH resources for SPS HARQ-ACK only (PUCCH resources configured in sps-PUCCH-AN-List-r16)**
* **Alt 4: PUCCH resources for dynamic HARQ-ACK (PUCCH resources configured in PUCCH-ResourceSet)**

**Proposal 3: Support defer HARQ-ACK for SPS PDSCH to a first slot/sub-slot containing the available PUCCH resource defined in proposal 2.**

**Proposal 4: It is supported that deferred SPS HARQ-ACK is multiplexed with dynamic scheduled HARQ-ACK in a same HARQ-ACK codebook.**

**Proposal 5: Both type-1 and type-2 HARQ-ACK codebook construction need to be enhanced to accommodate the deferred SPS HARQ-ACK bits.**

**Proposal 6: For type-1 HARQ-ACK codebook, if the originally configured or defined K1 set is {K1,1, K1,2……K1,n}, it should be updated to be the union of { K1,1 ，K1,1+T-1 },{ K1,2 ，K1,2+T-1 }…{ K1,n ，K1,n+T-1 }, where T is the periodicity in semi-static UL/DL configuration or the periodicity of periodically configured PUCCH resource/slot.**

**Proposal 7: For type-2 HARQ-ACK codebook, the total bits to be appended for one activated SPS configuration needs to contain all the HARQ-ACK bits for SPS PDSCH reception activated from slot n- K1,c -T+1 to slot n- K1,c, where K1,c is the PDSCH-to-HARQ-feedback timing value in DCI activating the corresponding SPS configuration.**

**Proposal 8: For SPS HARQ skipping for ‘skipped’ SPS PDSCH, dynamic indication of skipped SPS PDSCH occasions is supported.**

**Proposal 9: Support Type 1 HARQ codebook based on sub-slot PUCCH config in R17.**

### R1-2101075 UE feedback enhancements for HARQ-ACK ETRI

**Proposal 1**: **Adopt Option 2 (re-transmitting HARQ-ACK) and further discuss Option 1 (deferring HARQ-ACK).**

**Proposal 2**: **Type-3 HARQ-ACK codebook having a subset of configured HARQ process is considered.**

**Proposal 3**: **For skipped SPS PDSCH, the ‘NACK skipping’ is introduced.**

**Proposal 4**: **The ‘NACK skipping’ is applicable only when one SPS HARQ-ACK bit is present.**

**Proposal 5**: **When more than one bits of SPS HARQ-ACK is transmitted, the HARQ-ACK bundling is introduced to reduce the overhead.**

**Proposal 6**: **Sub-slot based PUCCH repetition is supported, and additionally consider more repetition factors are required.**

**Proposal 7**: **The scheduling DCI can indicate the repetition factor for PUCCH.**

### R1-2101114 UE feedback enhancement for HARQ-ACK Xiaomi

*Proposal 1: The definition of “next available PUCCH” should consider payload size for each PUCCH resource to avoid unbalanced payload issue.*

***Proposal 2: gNB can take load balancing into consideration and explicit or implicit indicate the mapping rule of actual SPS PDSCH (M) transmission and available PUCCH resources (N) within a time window based on slot configuration period.***

***Proposal 3: As for*** ***dynamic triggering of a one-shot / Type-3 CB type of re-transmission, some enhancements can be considered for HARQ-ACK codebook reduction.***

***Proposal 4: Alt 1 and alt 2 for SPS HARQ payload size reduction should be discussed jointly with SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCH and we prefer alt1.***

***Proposal 5: For alt 3and alt 4, HARQ bundling granularity or certain SPS configurations can be configured by gNB through RRC signal and mechanism can be dynamically triggered by gNB through MAC-CE/DCI.***

***Proposal 6: Retransmission of cancelled HARQ issue can be discussed jointly with the alt 2 of “SPS HARQ-ACK dropping for TDD systems”.***

***Proposal 7: It is better to support Back-to-back PUCCH repetition for short format PUCCH, and support Sub-slot based PUCCH repetition for long format PUCCH respectively.***

***Proposal 8: Enhancement for Type 1 HARQ codebook based on sub-slot PUCCH config should be low priority.***

### R1-2101201 On HARQ-ACK reporting enhancements Samsung

**Proposal 1: Support option 1 (deferring HARQ-ACK until a next available PUCCH) for SPS HARQ-ACK dropping in TDD.**

**Proposal 2: Support using PUCCH resources configured in both *sps-PUCCH-AN-List-r16* and *PUCCH-ResourceSet* to transmit HARQ-ACK of SPS PDSCH in TDD.**

**Proposal 3: SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCHs is not supported.**

**Proposal 4: Support skipping of a PUCCH transmission with NACK-only HARQ-ACK information.**

**Proposal 5: Support sub-slot based PUCCH repetitions for all PUCCH formats.**

**Proposal 6: Use an UL grant scheduling a PUSCH without UL-SCH to request HARQ-ACK information that was multiplexed in a dropped PUSCH/PUCCH transmission.**

**Proposal 7: Consider potential support of Type-1 HARQ-ACK codebook based on sub-slot PUCCH configuration subject to minimal additional specification/implementation complexity.**

* **Determine candidate UL sub-slots and corresponding DL slots for candidate PDSCH receptions based on the HARQ-ACK timing set (sub-slot-level K1) and number of UL sub-slots *N* per UL slot on top of existing procedure for different DL/UL numerologies.**
* **Do pruning based on TDD configuration and SLIVs for each DL slot, wherein the SLIVs end in candidate UL sub-slots.**

**Proposal 8: Consider potential Type-1 HARQ-ACK codebook enhancements for intra slot repetition and for removing duplicated HARQ-ACK information in Rel-17.**



**Figure 2. An example of extended SLIV for intra slot repetition**

**Proposal 9: Consider only inter-band CA for supporting PUCCH cell selection for PUCCH transmission in Rel-17.**

**Proposal 10: The HARQ-ACK timing indicator counts only slots with PUCCH resources for PUCCH carrier switching.**

**Proposal 11: 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.**

### R1-2101290 HARQ-ACK enhancements for IIoT and URLLC InterDigital, Inc.

***Proposal 1:*** *The UE can be dynamically triggered to transmit Type-3 HARQ-ACK CodeBook to retransmit a dropped SPS HARQ-ACK.*

***Proposal 2:*** *The UE can be triggered to transmit only the SPS HARQ-ACK(s) of PUCCH(s) that collide with DL or flexible symbols.*

***Proposal 3:*** *To reduce the SPS HARQ payload size:*

* *The UE can be configured to skip NACK transmission or skip ACK transmission (Alt. 1 and Alt2) per SPS configuration.*
* *The UE can be configured to disable HARQ-ACK transmission per SPS configuration (Alt. 4)*

***Proposal 4:*** *The UE can skip NACK transmission for skipped SPS PDSCH (Alt. 1).*

***Proposal 5:*** *The UE can retransmit a cancelled HARQ using enhanced Type 3 CB.*

### R1-2101378 Views on UE feedback enhancements for HARQ-ACK Apple

**Observation: If non-integer periodicity for DL SPS can be configured, HARQ feedback overhead can be reduced compared with solutions available in Rel-16.**

**Proposal 1: Without changing the current SPS configuration design, consider the introduction of jitter window around a nominal arrival time to limit occasions for DL SPS reception and HARQ generation/feedback.**

**Proposal 2: HARQ bundling is supported for non-skipped SPS PDSCHs. With N SPS PDSCH transmission occasions within a jitter window,** $⌈log\_{2}(2×N+1)⌉$ **bits are used for** $2×N+1 $**code states which include the successful/failed decoding at one of those N occasions or no detection of PDSCH at any of those N occasions.**

**Proposal 3: 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”.**

### R1-2101459 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated

***Proposal 1: gNB explicitly requests via DCI for a UE to transmit modified HARQ-ACK codebook Type 3, in which the UE reports #N (a number N of) HARQ-ACK feedback for #N SPS HARQ-IDs occurring after a time instant t0.***

***Proposal 2: Study the following two options for empty SPS indication.***

* ***Option 1: Explicit DCI indicating a single or multiple empty (‘skipped’) SPS PDSCH occasion.***
* ***Option 2: send a special DMRS sequence on nominal DMRS OFDM symbols in a SPS occasion to indicate the SPS occasion is empty.***

***Proposal 3:* *Support dynamic bundling/compression of UCI.***

***Proposal 4: Support modified HARQ-ACK codebook Type 3 for retransmission of cancelled HARQ-ACK.***

***Proposal 5: Support compress multiple messages in HARQ-ACK codebook with small probability into a single message, to reduce HARQ-ACK payload size.***

***Proposal 6: Support NACK only HARQ-ACK feedback in which only NACK transmission takes place and ACK is skipped.***

***Proposal 7: With PUCCH carrier switch, similar to Rel-15, the slot to transmit HARQ-ACK follows the K1 indicated in DCI, and the granularity of K1 follows the numerology of PCC.***

***Proposal 8: With PUCCH carrier switch, the following static rule is applied to determine the CC to transmit HARQ-ACK, in a given slot.***

* ***The lowest indexed CC which has enough UL OFDM symbols to accommodate the HARQ-ACK PUCCH resource is selected to transmit the HARQ-ACK.***

***Proposal 9: In Rel-17, do not support simultaneous HARQ-ACK transmission on multiple CCs.***

***Proposal 10: Use MAC-CE to switch between multiple sub-slot configurations for HARQ-ACK feedback.***

***Proposal 11: Support sub-slot based Type-1 HARQ-ACK codebook construction in NR Rel-17. A PDSCH occasion (i.e., time-domain resource allocation) is associated with an uplink sub-slot that contains the end of the PDSCH occasion.***

### R1-2101539 UE feedback enhancements for HARQ-ACK Sharp

**Proposal 1:**

* To avoid SPS PDSCH HARQ-ACK dropping for TDD, the SPS HARQ-ACK is allowed to be transmitted in a later PUCCH by deferring HARQ-ACK until the first available valid PUCCH resource.

**Proposal 2:**

* **‘NACK skipping’ for (skipped) SPS PDSCH is supported**.

**Proposal 3:**

* As a potential solution for retransmission of cancelled HARQ and/or SPS HARQ-ACK dropping, support Type-3 HARQ-ACK codebook corresponding to mixed priorities.

### R1-2101612 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.

**Proposal 1: Support both option 1 and option 2 to avoid SPS HARQ-ACK dropping for TDD.**

**Proposal 2: 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:**

* **the PUCCH resource in the sub-slot/slot doesn’t exceed latency limitation (e.g. K1)**
* **the PUCCH in the sub-slot/slot has no collision with any invalid symbol, where the invalid symbol includes semi-static DL symbol and semi-static flexible symbol when SFI is configured.**

**Proposal 3: Possible PUCCH resource can be SPS HARQ-ACK resource and dynamic HARQ-ACK resource.**

**Proposal 4: The “next available PUCCH resource” can consider an additional condition that “REs of the PUCCH resource in the sub-slot/slot allowed for SPS HARQ-ACK deferring can be configured/indicated by NW”.**

**Proposal 5: SPS HARQ-ACK can be deferred when conditions for latency and TDD collision are satisfied.**

* **With regard to TDD collision condition, SPS HARQ-ACK deferring can be applied for SPS HARQ-ACK dropping due to collision with semi-static DL symbol and SSB/CORESET#0 symbol, and also collision with semi-static flexible symbols considering SFI indication/missing and DL grant DCI.**

**Proposal 6: If SPS HARQ-ACK is deferred to a slot/sub-slot where UE will report HARQ-ACK (with the same priority) indicated by K1 (i.e. non-deferred HARQ-ACK), one HARQ-ACK CB is generated for deferred SPS HARQ-ACK bits and non-deferred HARQ-ACK bits.**

* **If the non-deferred HARQ-ACK bits include HARQ-ACK associated with DCI(s), PUCCH resource is determined based on the PRI indicated by associated DCI(s).**
* **If the non-deferred HARQ-ACK bits only include SPS HARQ-ACK without associated DCI,**
	+ **If the determined PUCCH resource is valid, HARQ-ACK will be reported on the PUCCH.**
	+ **If the determined PUCCH resource is invalid, SPS HARQ-ACK will be further deferred if deferring condition is met.**

**Proposal 7: 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 8: Discuss whether DCI 1\_1 can be simultaneously configured with one-shot HARQ-ACK feedback and priority indicator field existing in DCI 1\_1. If permitted, discuss how to construct type 3 HARQ-ACK CB considering different priorities of HARQ-ACK for different HARQ process IDs.**

**Proposal 9: If optimization for type 3 HARQ-ACK size reduction is supported, reported HARQ-ACK in type 3 is determined as HARQ-ACK bits of HARQ-ACKs in a time window.**

**Proposal 10: Support DCI indicating skipping pattern for multiple SPS PDSCH occasions. More details need to be further studied such as DCI format, indication for one or multiple SPS configurations, skipping pattern application time and update, etc.**

**Proposal 11: For SPS HARQ payload size reduction (of non-skipped SPS PDSCH),**

* **Support HARQ-ACK bundling in condition that dynamic indicated SPS skipping pattern is supported.**
* **FFS whether to support ACK skipping in condition that dynamic indicated SPS skipping pattern is supported.**
* **FFS whether to support HARQ-ACK disabling /skipping for certain SPS configurations, including details on whether/how to skip HARQ-ACK of SPS PDSCH for the case when SPS HARQ-ACK and dynamic HARQ-ACK to be reported in one type 1 HARQ-ACK CB.**
* **NACK skipping is not supported.**

**Proposal 12: Support repetition of short PUCCH formats and sub-slot based PUCCH repetition.**

**Proposal 13: Support one-shot HARQ feedback for the retransmission of cancelled HARQ.**

**Proposal 14: Support type 1 HARQ codebook for sub-slot based HARQ-ACK feedback in Rel.17.**

**Proposal 15:**

* **Further study PUCCH carrier switching for HARQ feedback based on the outcome of the processing order of intra-UE UL multiplexing/prioritization and UL cancellation due to TDD configuration in Rel.16 URLLC.**
* **Only focus on PUCCH carrier switching based on semi-static configuration if PUCCH carrier switching is supported.**

### R1-2101675 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.

* ***Proposal 1: Support option 1, i.e., Deferring HARQ-ACK until a next (e.g., first) available PUCCH, and discuss whether to support option 2 for the cancelled HARQ-ACK (not only for SPS HARQ-ACK).***
* ***Proposal 2: The DL and flexible symbols configured by semi-static DL/UL configuration are considered to determine SPS PUCCH collision.***
* ***Proposal 3: Further consider the following two options to define the next available PUCCH slot with considering latency and balance of SPS HARQ-ACK.***
* ***Proposal 4: The PUCCH resources for HARQ-ACK information of SPS configuration(s) are considered as the available valid PUCCH resource.***
	+ ***FFS: if multiple SPS PDSCHs are configured***
	+ ***FFS: when SPS release DCI is received***
* ***Proposal 5: If SPS HARQ-ACK skipping is supported in Rel-17 URLLC/IIoT WI, one of ACK skipping or NACK skipping can be configurable to a UE per SPS configuration.***
* ***Proposal 6: One-shot HARQ-ACK codebook is used for re-sending of cancelled HARQ-ACK information and the following should be further enhanced.***
	+ ***Reduction of Type-3 CB size, Determination of type-3 CB priority, Support of DCI format 1\_2 triggering type-3 CB, and inclusion of HARQ-ACK of SPS release DCI.***
* ***Proposal 7: To support type-1 HARQ-ACK codebook with sub-slot K1 granularity, the following general rules are considered.***
* For a given (***sub-slot-level***) K1 value *k1*, find the DL slot corresponding to the UL sub-slot *n*-*k1.*
	+ Validity of each SLIV in a TDRA table *R* for the DL slot is checked. The invalid SLIVs are removed from the TDRA table *R*.
		- The validity is checked based on semi-static UL/DL configuration, i.e., if a symbol corresponding to an SLIV overlaps with semi-static UL symbol, then the SLIV is invalid.
		- And the validity is further checked based on the last symbol of an SLIV, i.e., the last symbol of an SLIV does not overlaps with the UL sub-slot *n-k1*, then the SLIV is invalid.
	+ If the TDRA table *R* is not empty, then generate type-1 HARQ-ACK codebook for the DL slot.
		- If a UE has no capability to receive more than one unicast PDSCH per DL slot, then one HARQ-ACK occasion is added to the type-1 HARQ-ACK codebook.
		- If a UE has capability to receive more than one unicast PDSCH per DL slot, overlapping of SLIVs are further checked and then find a set of SLIVs to be represented as one HARQ-ACK occasion.