**3GPP TSG-RAN WG1 Meeting #105-eR1-210XXXX**

e-Meeting, May 19th – 27th, 2021

**Agenda item: 8.3.1.1**

**Source: Moderator (Nokia)**

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

**Document for: Discussion and Decision**

# Introduction

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

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

* 1st check point: 5/21
* 2nd check point: 5/25
* Final check: 5/27

Based on Mr chairman’s guidance, only ‘Retransmission of cancelled HARQ’ and ‘PUCCH carrier switching for HARQ feedback’ are to be handled during RAN1#105-e in AI 8.3.1.1. Therefore, any additional input provided by companies is not considered in this moderator summary, but related proposals are still included in Appendix B.

**This document is structured as follows:**

* Sections 2 focuses on Retransmission of cancelled HARQ
* Section 3 focuses on PUCCH carrier switching for HARQ feedback
* There are two appendices, Appendix A containing the RAN1 agreements reached in AI 8.3.1.1 so far and Appendix B summarizing the companies’ proposals for easier referencing.

# Retransmission of cancelled HARQ

## 2.1 Summary of companies input in their contributions

On the **scenarios to be supported / focused on**, the following input was provided:

* Focus on LP HARQ-ACK: ZTE [4] (LP prioritized, same principle could be applied to HP HARQ)
* Equal support for LP & HP HARQ-ACK: vivo [5] (unified solution), Mediatek [23] (unified solution), APT/FGI [26]
* Canceled PUSCH carrying HARQ-ACK (e.g. due to intra-UE mux): QC [9] (see description of scenario 2.1, support related enhancements)
* Dropping LP PUCCH should not be the driver: QC [9]
* Focus on /main solution is network controlled mechanism (not autonomous re-tx): QC [9]
* SPS HARQ-ACK deferral is only able to handle the collision with semi-static DL symbols – for dropping concerning flexible symbols this is not sufficient: China Telecom [11], Intel [12]

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

* **Alt. 0 (10 Yes – 1 No) – Type 3 CB enhancements that are not codebook size related for Rel-16 URLLC enhancements (unchanged codebook construction, i.e. without smaller size)** 
  + **PHY priority indication** in the triggering DCI of the PUCCH carrying the Type 3 CB: Ericsson [1], Nokia/NSB [3], Spreadtrum [6], CATT [7], Apple [13], Interdigital [19], Sharp [21], DoCoMo [22], APT/FGI [26], WILUS [27] – **No:** QC [9]
    - Focus on this aspect, before discussing payload size optimizations: Sharp [21]
  + Support Type 3 CB **triggering using** **DCI format 1\_2**: Ericsson [1], Nokia/NSB [3], CATT [7], China Telecom [11], Sony [14] (for Rel-16 Type 3 CB), Mediatek [23] (for Rel-16 Type 3 CB), APT/FGI [26], WILUS [27]
  + Do not support Type 3 CB triggering using DCI format 0\_1: QC [9]
* **Alt. 1 (18 Yes – 3 No)- Support enhanced Type 3 CB(s) with smaller size (compared to Rel-16):** 
  + *Definition:* 
    - *The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook is at least determined by RRC configuration*
    - *The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)*
  + **Yes:** Ericsson [1], HW/HiSi [2] (based on RRC configuration only, but not essential), Nokia/NSB [3], vivo [5], Spreadtrum [6], CATT [7], QC [9], OPPO [10], China Telecom [11], Intel [12], Apple [13], Panasonic [15] (but not essential), ETRI [16], Interdigital [19], LGE [20], DoCoMo [22], Moto/Len [25] (no triggering needed), WILUS [27]
  + **No:** Sony [14], Samsung [18] (unnecessary / not meaningful), Mediatek [23] (reuse as is)
  + **Suggested Type 3 CB enhancements with smaller size:**
    - Allow the **dynamic triggering to indicate a sub-set of HARQ processes / cells or different Rel-17 Type 3 CBs**: Nokia/NSB [3], ZTE [4], vivo [5] (based on configured lists), Spreadtrum [6], QC [9] (?), OPPO [10] (subset of cells), Intel [12] (index to a configured table), Apple [13], NEC [17], Interdigital [19], LGE [20], APT/FGI [26] – **No - only single Rel-17 Type 3 CB size supported at a time (e.g. based on RRC configuration):** Ericsson [1] (only activated CCs), HW/HiSi [2], CATT [7], China Telecom [11], Panasonic [15] (or activation), ETRI [16], DoCoMo [22] (RRC or time window)
      * Only for DCI not scheduling PDSCH: Nokia/NSB [3] (reuse unused field, for DCI scheduling PDSCH only a single fixed CB can be triggered), vivo [5], Interdigital [19] (‘use unused bitfields)
      * Also for DCI scheduling PDSCH: Spreadtrum [6], Intel [12] (?)
      * Index to configured lists / tables: Nokia [3], vivo [5], Intel [12]
      * Indication to differentiate SPS HARQ collision, cancelled HARQ or if both should be re-transmitted: QC [9] (.. but conflicting proposal 7?)
      * Triggering DCI indicating the HARQ-IDs: QC [9]
      * Using RNTI (for M=2): NEC [17], LGE [20] (for SPS & general Type 3 CB)
      * Explicit indication in DCI (M>2): NEC [17], LGE [20] (reuse or extend one-shot request field)
      * **Priority based CB construction / CB size** (based on the priority indication): ZTE [4], Apple [13], Interdigital [19], LGE [20], APT/FGI [26] – **No (i.e. same CB)**: Ericsson [1] (all HARQ processes), Nokia/NSB [3], Spreadtrum [6], CATT [7], QC [9], DoCoMo [22], WILUS [27]
        + Separate configuration of NDI & CBG for ‘LP & HP’ Type 3 CB: Apple [13], APT/FGI [26]
        + Separate configuration of applicable CCs and HARQ-IDs for ‘LP & HP’ Type 3 CB: Apple [13]
        + Pre-configured CB size per priority: Interdigital [19]
        + Only applicable to SPS Type 3 CB: LGE [20]
    - Only **SPS HARQ processes**: CATT [7], China Telecom [11] (activated ones), Intel [12] (configured or activated), ETRI [16] (activated ones), NEC [18], LGE [20]
      * Including dynamic indication of subset of SPS configurations: NEC [18]
      * Including a reduced set of DL HARQ processes of SPS configurations using RRC: NEC [18]
      * PUCCH resource determination needs to be studied: NEC [18]
      * SPS HARQ Type 3 CB per priority: LGE [20]
    - Only **HARQ processes within a time window** (reference is triggering DCI): QC [9], OPPO [10] (for SPS only), DoCoMo [22]
    - Only consider **activated CCs**: Ericsson [1], China Telecom [11], Panasonic [15], ETRI [16]
    - Only **subset of configured CCs**: Nokia/NSB [3], QC [9], Intel [12], Moto/Len [25]
    - Only configured **subset of HARQ processes**: Nokia/NSB [3], QC [9], LGE [20], Moto/Len [25]
    - How to **differentiate Rel-16 or Rel-17 Type 3 CB(s)**:
      * Bit on the DCI: Spreadtrum [6], QC [9]
      * Based on RNTI: ETRI [16]
      * Based on RRC: Intel [12], NEC [17]
    - Define a **reference time** for the Type 3 CB construction **to avoid ambiguity**: ETRI [16]
    - **Autonomous Type 3 CB on CG PUSCH**: Moto/Len [25] (as for NR-U operation)
    - **Include SPS release HARQ-ACK** to Type 3 CB: WILUS [27]
* **Alt. 3 (9 Yes – 2 No) – DCI scheduling new PUCCH resource for HARQ re-transmission / One-shot triggering of dropped HARQ-ACK on PUCCH:**
  + *Definition:* 
    - *The UE is provided a trigger and a PUCCH resource to transmit the dropped HARQ-ACK.*
      * *This may or may not include in addition some time windowing*
  + **Yes:** Nokia/NSB [3], ZTE [4], CATT [7] (‘if supported’, see detail below), QC[9], OPPO [10], Sony [14], Samsung [18], DoCoMo [22] (if time window for Type 3 CB not supported), Mediatek [23]
  + **No:** Ericsson [1] (no need), vivo [5] (no need)
  + **Details:**
    - For triggering with DL assignment on PUCCH, support dynamic indication of the dropped PUCCH instance: Nokia/NSB [3], CATT [7] (offset between triggering DCI and the dropped PUCCH), OPPO [10] (x-bit explicit indication) – **No** (there is no need for indication): Samsung [18]
    - Triggering possible as soon as the conflict is determined (e.g. after the DCI scheduling HP PUCCH which cancels the LP PUCCH): ZTE [4]
    - Indication of requested HARQ processes: QC [9]
    - Implicitly, if scheduling a re-transmission of a HARQ process whose HARQ CB had been cancelled: OPPO [10]
    - Implicitly, the original DL assignment includes already the information of the re-transmission in case of dropping (i.e. DL assignment indicating PRI, K1, PRI\_rext, K1\_retx): Intel [12]
    - Trigger is a DL assignment without DL-SCH / PDSCH: Sony [14]
    - Consider all 3 options (last dropped, timing window and/or dynamic indication): Sony [14]
    - Apply a time window to define the HARQ-ACK to be re-transmitted: DoCoMo [22]
* **Alt. 4 (5 Yes – 2 No) – DCI scheduling new PUSCH for HARQ re-transmission / One-shot triggering of dropped HARQ-ACK on PUSCH:**
  + *Definition:* 
    - *The UE is provided a trigger and a PUSCH resource to transmit the dropped HARQ-ACK.*
      * *This may or may not include in addition some time windowing*
  + **Yes:** Nokia/NSB [3], ZTE [4], Sony [14], Samsung [18], Mediatek [23]
  + **No:** Ericsson [1] (no need) , vivo [5] (no need)
  + **Details:**
    - For triggering with UL grant on PUSCH, only support for re-transmission (with the same CB mapped): Nokia/NSB [3] – **No**: Samsung [18] (applicable for each PUSCH)
    - Triggering possible as soon as the conflict is determined (e.g. after the DCI scheduling HP PUCCH which cancels the LP PUCCH): ZTE [4]
    - Trigger is an UL grant without UL-SCH / PUSCH: Sony [14]
    - Consider all 3 options (last dropped, timing window and/or dynamic indication): Sony [14]
    - Similar handling of stored HARQ-ACK info as A-CSI on PUSCH without UL-SCH: Mediatek [23]
* **Alt. 5 (1 Yes) – Automatic re-tx of canceled HARQ-ACK (if multiplexed on PUSCH) on the PUSCH re-transmission with the same resource allocation:** QC [9]
  + Limited to UL-CI operation (i.e. dropping due to DCI format 2\_4 reception): QC [9]
  + If a PUSCH incl. HARQ is canceled, the cancelled HARQ-ACK is multiplexed on the PUSCH re-transmission automatically with the same resource allocation including same NDI, TBS, MCS, HARQ Process ID: QC [9]
  + Only HARQ-ACK is to be re-transmitted (drop CSI): QC [9]
  + No multiplexing of new UCI on the PUSCH re-tx: QC [9]
  + No support for partial re-transmission of cancelled HARQ-ACK bits: QC [18]
  + Can be configured together with Type 3 CB operation and mapped to the earlier occasion of the Type 3 CB or the PUSCH re-transmission: QC [9]
* **Alt. 6 (1 Yes – 1 No): Enhanced Type 2 CB:** Clarification that PDSCH grouping for Enh-Type2 CB is within each PHY priority:vivo [5] (then readily available) – No: Samsung [18] (not generally feasible)

**Multiplexing of re-transmitted and new HARQ-ACK information**:

* Concatenation of two Type 1 CBs (re-tx CB is appended): QC [9] (modifications to Type 1 CB will result in high specs impact, issues in case of missed UL-CI)
* Concatenation of two Type 2 CBs (re-tx CB is appended): QC [9] (modifications to Type 1 CB will result in high specs impact, issues in case of missed UL-CI)

**Additional things that need consideration:**

* Interaction of SPS HARQ skipping (if supported) and re-transmission of cancelled HARQ: Apple [13]

## 2.2 1st Round / preparation for 1st GTW session

**Moderator comments:**

Looking at the input given, the following is noted:

* There are **enhancements to the Rel-16 Type 3 CB triggering** suggested to take Rel-16 URLLC enhancements into account (**Alt. 0**), **that do NOT change the REl-16 Type 3 CB construction / definition / size**, but triggering with DCI format 1\_2 and PHY priority handling of the PUCCH carrying the Rel-16 Type 3 CB is suggested (noted as Alt. 0). **About 10 companies** suggesting such enhancements.

It is the moderator’ understanding, that these suggested enhancements are somehow independent of any real Type 3 CB enhancements in terms of size or configurability (of Alt. 1) and therefore could be independently agreed. Both suggested enhancements there seem to require only very minor specification and implementation impact.

***So maybe we could try to agree such enhancements at least for the Rel-16 Type 3 CB (so independently of the decision to support Type 3 CB of smaller size, i.e. Alt. 1)***

* There is rather strong support from companies **(~18 companies) suggesting Type 3 CB with smaller size at least based on RRC configuration (Alt. 1, based on the definition and as discussed already during RAN1#104bis-e).**

On the details, the positions are slightly diverse in what could be actually supported. This includes if only a single Rel-17 HARQ-ACK Type 3 CB of smaller size can be configured or if dynamic indication of one of more than one configured Rel-17 HARQ-ACK Type 3 CB of smaller size is possible. The same applies to if different RRC configuration of the Rel-16 Type 3 CB parameters (e.g. CBG & NDI) should be possible for PHY priority 0 & 1. And then there are varying positions on how a single reduced size Rel-17 Type 3 CB could look like (such as activated CCs only, SPS HARQ processes only, configured subset of HARQ processes and/ CCs, …).

The moderator has the feeling, that discussing more on the details (of the previous paragraph) before having a generic decision as we tried during RAN1#104bis-e is not really helping as the companies that do not want to see enhancements to Type 3 CB size are suggesting from their side one-shot-triggering of PUSCH and/or PUCCH (i.e. Alt. 3 / Alt. 4, as the codebook size is then only covering dropped HARQ-ACK) independently of the detailed definition of a Rel-17 Type 3 CB of reduced size. ***Therefore, the moderator thinks we need to have a generic decision if at least one Rel-17 Type 3 CB of reduced size is supported.***

* Looking at the **one-shot triggering for new PUCCH resource for HARQ-ACK retransmission using DL assignment (Alt. 3)** there seems to be still good support for it but clearly less compared to Alt. 1 (9Y vs. 2N). There seems to be slightly more support for Alt. 3 compared to Alt. 4 of re-transmission on new PUSCH using an UL grant to triggering (5Y vs. 2N).

On the details, there are mixed opinions how to determine the HARQ-ACK codebook that is dynamically explicitly triggered for retransmission (window, last dropped, dynamically indicated PUCCH occasion and/or HARQ-ID and/or CB containing the HARQ-DI of the scheduled PDSCH). Also implicit triggering in the initial DL assignment is suggested.

***As this seems to be more popular enhancement enabling the CB size tailored to the dropped HARQ-ACK (compared to Alt. 4), it is suggested to see if Alt. 3 could be supported and at least in the initial phase focus the discussions more on Alt. 3 (compared to Alt. 4 below)***

* For **one-shot triggering for new PUSCH for HARQ-ACK retransmission using DL assignment (Alt. 4) using an UL grant for triggering (5Y vs. 2N)** there seems to be less support compared to Alt. 4 (and less technical details provided by supporting companies). As discussed above, it is ***suggested to focus the discussions at least initially not on Alt. 4 but more on Alt. 3*** (as there seems to be more support by companies and is at least more in line with the HARQ-ACK triggering using DL assignments for Enh. Type 2 and Type 3 CB).
* **For Alt. 5 &Alt. 6, only one company each mentioned the support in their contribution.** Therefore, the discussions on these are suggested to take place after having more clarity on other alternatives with more indicated support.

Based on the current status and summary above, the following proposals come to mind here with respect to Alt. 0, 1 and Alt. 3:

**FL proposal 2.1: Support Rel-16 Type 3 CB triggering using DCI format 1\_2.**

* **The triggering using DCI format 1\_2 is RRC configured.**
* ***Note: the Rel-16 Type 3 CB parameters, construction & size is not affected***

**Question 2.1.1: Do you support FL proposal 2.1? (Only Yes / No here – please add your company name, please provide your additional comments to next question / table below separately)**

|  |  |
| --- | --- |
| *Yes - Support* | Sharp, CATT, OPPO, Spreadtrum |
| No – Do not support |  |

**Question 2.1.2: Do you have any additional comments on FL proposal 2.1, including your arguments for or against the support?**

|  |  |
| --- | --- |
| *Company* | *Additional comments* |
| Sharp | Agree with FL proposal and I wonder whether the formation could be improved. As mentioned by FL, Alt.0 can be independently discussed from Alt.1 and others. Then, it would be clearer to change Alt.0 from an alternative to an independent proposal/topic. |
| OPPO | Further clarification. If Rel-16 Type 3 CB triggering using DCI format 1\_2 is supported, the mechanism that Type 3 CB request with/without PDSCH transmission will be reused for DCI format 1\_2 directly. |
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**FL proposal 2.2: Support PHY priority handling for a PUCCH carrying the Rel-16 Type 3 CB in Rel-17.**

* **The indicated PHY priority in the triggering DCI defines the PHY priority of the PUCCH carrying the Rel-16 Type 3 CB.**
* ***Note: the Rel-16 Type 3 CB parameters, construction & size is not affected by the indicated PHY priority***

**Question 2.2.1: Do you support FL proposal 2.2? (Only Yes / No here – please add your company name, please provide your additional comments to next question / table below separately)**

|  |  |
| --- | --- |
| *Yes - Support* | Sharp, CATT, OPPO, Spreadtrum |
| No – Do not support |  |

**Question 2.2.2: Do you have any additional comments on FL proposal 2.2, including your arguments for or against the support?**

|  |  |
| --- | --- |
| *Company* | *Additional comments* |
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**FL proposal 2.3: Support enhanced Type 3 CB(s) with smaller size (compared to Rel-16)**

* + ***Definition of enhanced Type 3 CB:*** 
    - ***The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook at least determined by RRC configuration***
    - ***The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)***

**Question 2.3.1: Do you support FL proposal 2.3? (Only Yes / No here – please add your company name, please provide your additional comments to next question / table below separately)**

|  |  |
| --- | --- |
| *Yes - Support* | Sharp, CATT (with additional constraint), OPPO, Spreadtrum |
| No – Do not support |  |

**Question 2.3.2: Do you have any additional comments on FL proposal 2.3, including your arguments for or against the support?**

|  |  |
| --- | --- |
| *Company* | *Additional comments* |
| Sharp | We support FL proposal in principle and are open to discuss. |
| CATT | We are in general supportive to enhance Type 3 CB to reduce the payload size with small specification impact, e.g. to include HARQ-ACKs for SPS PDSCH only, and/or to include HARQ-ACKs for the DL HARQ processes of active DL CCs only. But we do not support further enhancements to construct enhanced Type 3 CB based on dynamic indication in DCI. If companies would like to do such enhancements, we think one-shot triggering is more efficient and has less specification impact. Therefore, we would like to add the sub-bullet in red in the proposal.  **Support enhanced Type 3 CB(s) with smaller size (compared to Rel-16)**   * + ***Definition of enhanced Type 3 CB:***      - ***The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook at least determined by RRC configuration***     - ***The codebook size of enhanced Type 3 HARQ-ACK codebook is not determined based on DCI indication***     - ***The codebook construction uses HARQ processes as a bases (i.e. ordered according to HARQ-IDs and serving cells)*** |
| Spreadtrum | Support FL proposal in principle and are open to discuss. |
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**FL proposal 2.4: Support one-shot triggering (by a DL assignment) of dropped HARQ-ACK on a new PUCCH resource**

* + ***Details are FFS***

**Question 2.4.1: Do you support FL proposal 2.4? (Only Yes / No here – please add your company name, please provide your additional comments to next question / table below separately)**

|  |  |
| --- | --- |
| *Yes - Support* | CATT, OPPO, Spreadtrum |
| No – Do not support |  |

**Question 2.4.2: Do you have any additional comments on FL proposal 2.4, including your arguments for or against the support?**

|  |  |
| --- | --- |
| *Company* | *Additional comments* |
| Spreadtrum | If enhanced Type 3 CB(s) with smaller size can be supported, the flexibility and resource efficiency of Alt. 3 may can also be appropriately obtained by enhanced Type 3 CBs. In addition, since some possible features under discussion of enhanced Type 3 CB are similar as Alt.3, such as time window and certain HP ID(s) constraint, we suggest to delay the discussion of detailed feature of Alt.3 after more details of enhanced Type 3 are determined. |
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# PUCCH carrier switching for HARQ feedback

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

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

Moreover, during RAN1#104, the following additional agreement was reached:

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

During RAN1#104bis, based on the discussions the definition, a hybrid operation of the earlier Alt. 1 and Alt. 2B was discussed which is now denoted as Alt. 1B, i.e. the following methods had been discussed during RAN1#104bis-e:

* ***Alt. 1- PUCCH carrier switching is based dynamic indication in DCI***
* ***Alt. 1A -*** ***PUCCH carrier switching is based dynamic indication in DCI for scheduled PUCCH (as for Alt. 1) and based on certain (semi-static) rules for configured PUCCH (as for Alt. 2B)***
* ***Alt. 2B - PUCCH cell switching is based on certain (semi-static) rules***
* ***Alt. 2C - PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells***

## 3.1 Summary of companies input in their contributions

**Motivation for PUCCH carrier switching:**

**Pros:**

* Reduce latency for different UL/DL configurations: Ericsson [1], HW/HiSi [2], Nokia/NSB [3], ZTE [4], QC [9], Intel [12], ETRI [16], Samsung [18], Interdigital [19], Mediatek [23], CAICT [24], WILUS [27]
* Dynamic load balancing & f-selective gain: HW/HiSi [2], CAICT [24]
* Use CC with higher reliability: QC [9]
* Improves network capacity / efficiency – reduces resource utilization: Mediatek [23]

**Cons:**

* Limited use case: vivo [5] (realistic deployment scenarios not yet identified), OPPO [10], Apple [13]
  + Reply: Identified use case is inter-band CA with unaligned frame boundary: CMCC [8], QC [9]
* Multiplexing on PUSCH already supported (based on Ran1#104-e Rel-16 agreement): vivo [5]

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

* **Do not support PUCCH carrier switching:** vivo [5](deployment scenarios not identied, multiplexing on PUSCH supported already when PUCCH is overlapping with SSB/semi-static DL symbols),
* **Alt. 1 - PUCCH carrier switching is based dynamic indication in DCI:** 
  + **Support (15?) :** Ericsson [1] (and/or Alt. 2C), HW/HiSi [2] (?), Nokia/NSB [3] (2nd preference), ZTE [4], CATT [7], CMCC [8] (Alt. 2C to complement for configured PUCCH), China Telecom [11], Intel [12] (for dynamic PUCCH, Alt. 2C for scheduled PUCCH), Panasonic [15], Samsung [18] (for scheduled PUCCH, Alt. 2C for configured PUCCH), Interdigital [19], LGE [20] (if feature is necessary), Mediatek [23], CAICT [24], APT/FGI [26] (?)
  + **No (1):** Apple [13] (exclude from further discussions)
  + **FFS (-):**
  + **Details:**
    - And indicated PUCCH carrier should not be changed further for UCI transmission: Ericsson [1]
    - PRI indicating the PUCCH carrier using extended PUCCH resource sets including different CCs: ZTE [4], Panasonic [15] (with potential size increase of PRI field), CAICT [24]
    - Add a carrier-switching field to the DCI: LGE [20], Mediatek [23]
    - The reference SCS of PDSCH to HARQ-ACK offset K1 is the SCS of the indicated target carrier: ZTE [4], China Telecom [11], Panasonic [15]
      * Issues with Type 1 CB and multiplexing of SPS PDSCH on scheduled PUCCH resource for mixed SCS identified: Nokia/NSB [3] (do not support mixed SCS)
    - The reference slot / SCS is determined by the smallest SCS: CATT [7]
      * Issues with Type 1 CB and multiplexing of SPS PDSCH on scheduled PUCCH resource for mixed SCS identified: Nokia/NSB [3] (do not support mixed SCS)
    - PUCCH carrier selection reliability due to missed DCI can be helped by not changing the indicated PUCCH carrier index: Panasonic [15], Interdigital [19], Mediatek [23]
    - Configure different K1 sets for carrier with different SCS (but the same set size): China Telecom [11], Panasonic [15] (either per carrier specific or SCS specific), CAICT [24] (per SCS)
    - Configure offset values for different SCS for the slot/sub-slot determination: Panasonic [15]
    - Consider MAC CE indication for SPS HARQ-ACK only: China Telecom [11]
    - SPS HARQ-ACK only switched, if overlapping dynamically indicated switched PUCCH: LGE [20], CAICT [24]
* **Alt. 1A - PUCCH carrier switching is based dynamic indication in DCI for scheduled PUCCH (as for Alt. 1) and based on certain (semi-static) rules for configured PUCCH (as for Alt. 2B)**
  + **Support (2) :** HW/HiSi [2], APT/FGI [26]
  + **No (4):** Nokia/NSB [3] , OPPO [10], China Telecom [11], CAICT [24]
  + **FFS (-):**
  + **Details:**
    - Multiplex SPS on the scheduled PUCCH resource in case of collision: HW/HiSi [2]
* **Alt. 2B – PUCCH cell switching is based on certain (semi-static) rules:**
  + **Support (4):** QC [9], NEC [17], DoCoMo [22], Moto/Len [25]
  + **No (3):** Nokia/NSB [3], OPPO [10], China Telecom [11]
  + **FFS (X):**
  + **Details:**
    - Reference slot (using K1) is determined by the PCell numerology: QC [9], China Telecom [11], NEC [17], DoCoMo [22],
    - Reference slot is determined by the largest SCS: NEC [17]
    - The order of the cell selection is to take the SCS into account: HW/HiSi [2] (first same SCS, then closes smaller SCS), China Telecom [11] (higher SCS carrier having priority)
    - First CC having enough UL symbols is selected: QC [9] (CC based on predefined order, lowest indexed CC), China Telecom [11] (predefined ordering of CCs, SS-UL symbols highest priority in the search), NEC [17] (in order of priority), DoCoMo [22] (‘no invalid symbols’, in order of serving cell index), Moto/Len [25] (carrier priorities)
    - If selected CC has larger SCS, select the earliest available slot in the set of multiple slots: QC [9], China Telecom [11], NEC [17]
    - If selected CC has smaller SCS, multiplexing of HARQ-ACK of different slot’s would be needed: Nokia/NSB [3], China Telecom [11]
    - Simplified solution proposal for Alt. 2B by QC [9]
      * Limited to 2 cells (PCell & one Scell)
      * PUCCH TX not possible on the PCell (based on K1 & PRI interpretation on PCell), transmit on the SCell by interpretating K1 and PRI using Scell numerology & Scell PUCCH config
      * Regarded as gNB error if transmission on the Scell is not possible
        + *Moderator question:* how about configured PUCCH? Is this then also a gNB error or only for scheduled PUCCH?
    - In the initial carrier, a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as needing carrier switching: China Telecom [11]
* **Alt. 2C - PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells –** 
  + **Support (6 + 3 for configured PUCCH):** 
    - **For configured & scheduled PUCCH (6):** Ericsson [1] (and/or Alt. 1), Nokia/NSB [3] (1st preference), Apple [13] (more suitable, if to be supported), ETRI [16] (?), DoCoMo [22], WILUS [27]
    - **For configured PUCCH only (dynamic indication / Alt.** **1 for scheduled PUCCH**) **(3)**: CMCC [8], Intel [12], Samsung [18]
  + **No (-):**
  + **FFS (-):**
  + **Details:**
    - Configure time-domain pattern directly defines the PUCCH slot: Nokia/NSB [3]
    - Reference SCS of the time-domain pattern could be the smallest SCS: China Telecom [11]
    - K1 uses the PCell numerology: China Telecom [11]
    - If selected CC has larger SCS, select the earliest slot in the set of multiple slots: China Telecom [11]
    - If selected CC has smaller SCS, multiplexing of HARQ-ACK of different slot’s would be needed: China Telecom [11]

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

* Configuration of pucch-Cell on PCell to indicate another serving cell within the same cell group to use for PUCCH: Ericsson [1]
* SCS / different numerologies within a PUCCH cell group:
  + No restriction / limitations on the SCS: Ericsson [1], ZTE [4] (for Alt. 1), CATT [7] (for Alt. 1), QC [9], China Telecom [11], Intel [12] (no issues identified), Panasonic [15], Mediatek [23]
  + Support PUCCH carrier switching only for cells with same UL SCS: Nokia/NSB [3], DoCoMo [22] (preferred)
    - Issues with Type 1 CB: Nokia/NSB [3]
    - Going from higher to lower SCS – overlapping PUCCHs from neighboring slots: Nokia/NSB [3]
    - Going from lower to higher SCS – unclear which slot is selected: Nokia/NSB [3]
      * Select the first available one: QC [9] – multiplexing timeline?
  + For Alt. 1, target carrier should be same or higher SCS: LGE [20]
* Discuss joint operation of PUCCH carrier switching and simultaneous PUCCH/PUSCH: Ericsson [1] (incl. simultaneous PUCCH/PUCCH)
  + PUCCH carrier switching is the first step, followed by PUCCH/PUSCH parallel transmission and/or UCI multiplexing on PUSCH in a second step: QC [9]
* Multiplexing limitations:
  + Any CSI supported: ETRI [15], LGE [20] (?)
  + No CSI multiplexed: Nokia/NSB [3], ZTE [4], Mediatek [23] (lower priority)
  + SR multiplexing: Yes: Nokia/NSB [3], Samsung [18] – No: ZTE [4], Mediatek [23] (lower priority)
  + SPS HARQ-ACK & DG HARQ-ACK are multiplexed: CATT [7], Nokia/NSB [3], LGE [20], – No: ZTE [4] (only DG PDSCH HARQ-ACK transmitted using Alt.1), QC [9] (?)
* PUCCH resource configuration:
  + Per CC: QC [9], Mediatek [23]
  + Combination of ‘per PUCCH group” and “per PUCCH carrier”: Mediatek [23]
  + Depending on the Alt. chosen: Nokia/NSB [3] (Alt. 2B may require same configuration)
  + Same number of PUCCH-configs expected (i.e. same handling for both PHY priorities): DoCoMo [22]
* Applicable cells for PUCCH carrier switching are configured by gNB: ZTE [4] (‘cell set’), QC [9] (per CC)
* Overlapping between PUCCH on switched cell and initial cell needs to be handled: CATT [7]
* PUCCH TPC operation on different CCS: NEC [17] (joint or separate TPC loop, handling of DCI format 2\_2), Mediatek [23] (separate TPC loop & TPC parameter settings)
* Compromise to support both, Alt. 1 and Alt. 2B (based on configuration):
* Should be limited to inter-band CA in Rel-17: Samsung [18]
* HARQ-ACK timing indicator counts only slots with PUCCH resources for PUCCH carrier switching:

## 3.2 1st Round / preparation for 1st GTW session

**Moderator comments / observations:**

Looking at the input given, the following is noted:

* There are still some company(s) not convince about the use-fullness of PUCCH carrier switching overall
* **Dynamic indication in the triggering DCI (Alt. 1) received most support by companies (15 Y vs. 1 N).** The arguments for the support of Alt. 1 include the ability for the gNB to dynamically indicate the PUCCH carrier to be selected as well as the simplicity of specification and operation. The drawback of supporting Alt. 1 (only) is that the handling of SPS HARQ-ACK (i.e. configured PUCCH) is not really supported if not multiplexed on a scheduled PUCCH – which was the reason for some companies during RAN1#104bis-e to suggest Alt. 1A. In this meeting, some companies are now suggesting to couple Alt. 1 for scheduled PUCCH with the support of Alt. 2C (which is simpler to specify and keeps control at gNB side as well) for configured PUCCH. Additionally, the signaling overhead in the DCI had been mentioned by some companies (

***Overall, looking at the strong support for Alt. 1 (compared to the other discussed alternatives) it seems that if PUCCH carrier switching is to be supported in Rel-17 then at least the support of Alt. 1 could be there.***

* **Alt. 1A tries to solve the short-coming of Alt. 1 with having additional semi-static rules for configured PUCCH, but there had been little support indicated (2Y vs. 4N).** The arguments from companies not supporting Alt. 1A had been the rather large specification effort (i.e. the combination of Alt. 1 and 2B).

***As there seem more companies thinking this should not be supported compared to companies actively supporting Alt. 1A, the moderator is initially trying to find some consensus on the other options including at least Alt. 1.***

* **Alt. 2B using semi-static rules to determine PUCCH carrier also received little support (4Y vs. 3N).** The advantages over Alt. 1 is the reduced DCI overhead and the handling of SPS HARQ-ACK (compared to Alt. 1 & 1A). The drawback mentioned by some companies is the complex specification (of the rules) as well as the little control for the gNB for the PUCCH carrier switching operation.

***As there seem more companies thinking this should not be supported compared to companies actively supporting Alt. 2B, the moderator is initially trying to find some consensus on the other options including at least Alt. 1.***

* **Alt. 2C of having a semi-static RRC configured time-domain pattern of PUCCH cells received the support by 6 companies (6Y vs 0N) for scheduled & configured PUCCH, with 3 companies mentioned to use this in cooperation with Alt. 1 for configured PUCCH (i.e. hybrid of Alt. 1 and Alt. 2C).** The mentioned advantages over Alt. 2B include the reduced specification effort / complexity as well as the ability to have some control at the gNB side. The mentioned drawbacks include the ability to react on dynamic change of TDD operation (e.g. SFI) as well as high RRC signaling overhead of the time domain pattern.

***From the feedback received, it seems that this option is maybe still worth considering. Potentially in combination with Alt. 1 to solve the problem of configured PUCCH operation.***

* **On the overall operation, there had been good input on the discussion of different SCS handling, PUCCH resource configuration, support for SR and/or CSI, beside some other issues.**

***It is the moderator’s understanding, that some of these points need specific discussion based on the Alternative(s) chosen in case PUCCH carrier switching is supported. Therefore, it would be preferable to first decide on the Alt.(s) to be supported in Rel-17 before being able to have detailed discussions on these issues.***

As discussed above, Alt. 1 received by far the highest support followed by Alt. 2C. Clearly the drawback of only supporting Alt. 1 is the limited support for configured PUCCH (e.g. SPS HARQ-Ack or SR on Scell), which some of the supporting companies of Alt. 1A, 2B and 2C pointed out. Thus, maybe some compromise to take the worries of the

So as input to the first GTW session based on the interest by different companies we could try the following two options:

* Option 1: We support Alt. 1 only (with the known limitations for configured PUCCH)
* Option 2: Compromise as suggested by some companies, we support Alt. 1 and Alt. 2C, including the combination of the two schemes
  + If Alt. 1 only is configured for the UE, the UE is operated with Alt. 1 only (with its limitations in terms of e.g. SPS HARQ-ACK)
  + If Alt. 2C only is configured, the UE operates based on Alt. 2C – i.e. the time domain pattern defines the PUCCH carrier for scheduled and configured PUCCH.
  + If both Alt. 1 and 2C are configured, the configured PUCCH operates using the Alt. 2C time domain pattern. If a dynamic indication of a PUCCH carrier is available, the PUCCH cell and the PUCCH resource is determined based on the dynamic indication in the DCI scheduling the PUCCH.

Maybe we could see (based on initial input by companies) which of the options to discuss during the GTW session:

**FL Proposal Option 1: PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH (i.e. Alt. 1) is supported in Rel-17.**

* ***Details are FFS***

**FL Proposal Option 2: PUCCH carrier switching based on dynamic indication in DCI scheduling a PUCCH (i.e. Alt. 1) and based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells (i.e. Alt. 2C) is supported in Rel-17.**

* **Dynamic indication and/or RRC configured time-domain pattern can be independently configured for the UE.**
* **If only dynamic indication (i.e. Alt. 1) is configured, the PUCCH carrier switching is only supported for scheduled PUCCH based on the indication in the DCI scheduled the PUCCH.**
* **If only the RRC time-domain pattern (i.e. Alt. 2C) is configured, the PUCCH carrier switching for configured and scheduled PUCCH is based on the configured time-domain pattern of applicable PUCCH cells.**
* **If both dynamic indication and RRC configured time-domain pattern are configured for the UE, the UE selects the PUCCH carrier based on the dynamic indication in the DCI scheduling a PUCCH. If a dynamic indication of a PUCCH carrier is not available, the UE applies the RRC configured time-domain pattern to determine the PUCCH cell.**
* ***Details are FFS***

**Question 3.1:** Please provide your views with respect to Option 1 and Option 2 FL proposals above. (Please add your company name below to the rows if you prefer / support Option 1 and/or Option 2 or none of the above, please provide your additional comments to next question / table below separately)

|  |  |
| --- | --- |
| *Option 1: Alt. 1 only* | CATT, OPPO |
| *Option 2: Alt. 1 & Alt. 2C* | CMCC, Spreadtrum |
| *None of the above* |  |

**Question 3.2:** Do you have any additional comments on FL proposal Option 1 / Option 2, including your arguments for or against the support for Option 1 / Option 2?

|  |  |
| --- | --- |
| *Company* | *Additional comments* |
| CATT | We currently prefer Option 1 although we are also open to support Alt. 2C. We would like to have more discussions on the details of Option 2 including the details of Alt. 2C and whether/how to support configuring Alt. 2C only etc. before agreeing on Option 2. |
| CMCC | A clarification: Option 1 does **NOT** support SPS HARQ-Ack, right? SPS is frequently applied in vertical industries so a solution supporting SPS is much more useful. |
|  |  |
|  |  |
|  |  |

# References

1. R1-2104217 HARQ-ACK Enhancements for IIoT/URLLC Ericsson
2. R1-2104262 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon
3. R1-2104309 HARQ-ACK Feedback Enhancements for URLLC/IIoT Nokia, Nokia Shanghai Bell
4. R1-2104326 Discussion on HARQ-ACK enhancements for eURLLC ZTE
5. R1-2104353 HARQ-ACK enahncements for Rel-17 URLLC vivo
6. R1-2104420 Discussion on HARQ-ACK feedback enhancements for Rel-17 URLLC Spreadtrum Communications
7. R1-2104512 UE feedback enhancements for HARQ-ACK CATT
8. R1-2104604 Discussion on UE feeback enhancements for HARQ-ACK CMCC
9. R1-2104663 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated
10. R1-2104802 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO
11. R1-2104854 Discussion on two aspects of UE HARQ-ACK feedback enhancements China Telecom
12. R1-2104899 On dynamic carrier switching and dropped HARQ feedback retransmission Intel Corporation
13. R1-2105097 Views on eIIoT/URLLC HARQ feedback enhancements Apple
14. R1-2105160 Retransmission of dropped HARQ-ACK for URLLC Sony
15. R1-2105188 Discussion on UE feedback enhancements for HARQ-ACK PANASONIC R&D Center Germany
16. R1-2105212 UE feedback enhancements for HARQ-ACK ETRI
17. R1-2105258 UE feedback enhancements for HARQ-ACK NEC
18. R1-2105302 HARQ-ACK Reporting Enhancements for URLLC Samsung
19. R1-2105399 HARQ feedback enhancements for IIoT and URLLC InterDigital, Inc.
20. R1-2105425 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics
21. R1-2105631 UE feedback enhancements for HARQ-ACK Sharp
22. R1-2105693 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
23. R1-2105732 On UE feedback enhancements for HARQ-ACK MediaTek Inc.
24. R1-2105750 UE feedback enhancements for HARQ-ACK CAICT
25. R1-2105766 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility
26. R1-2105819 Discussion on UE feedback enhancements for HARQ-ACK Asia Pacific Telecom, FGI
27. R1-2105872 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.

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

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

Agreements:

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

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

Agreements:

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

Agreements:

Study further at least the following schemes:

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

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

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

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

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

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

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

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

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

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

**RAN conclusion on IIoT scope:**

* For handling of the PUCCH repetitions it is proposed to proceed as follows:

1. RAN1 to continue discussion on PUCCH repetition, whether to specify or not, in the IIoT/URLLC WI for single TRP.
   1. The following items are not within scope of the continued discussions in the IIoT/URLLC WI:
      1. DMRS-less PUCCH with UCI payload up to 11 bits
      2. PUSCH-repetition-Type-B like PUCCH repetition
      3. DMRS bundling across PUCCH repetitions
2. PUCCH repetition issues with multi-TRP to be handled in Fe-MIMO WI.

* For the UE CSI/HARQ-ACK feedback enhancements in the IIoT/URLLC WI, RAN1 work to continue the discussions. Status to be checked in March if any RAN level guidance needed.
  + RAN1 to continue discussion on A-CSI on PUCCH, whether to specify or not.

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

Agreements:

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

Agreements:

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

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

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

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

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

* FFS: Support for slot-based PUCCH repetition

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

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

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

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

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

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

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

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

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

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

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

**Conclusion:**

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

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

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

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

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

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

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

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

# Appendix B: Summary of companies’ proposals

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

### R1-2104217 HARQ-ACK Enhancements for IIoT/URLLC Ericsson

**Observation 1 Type-3 HARQ-ACK codebook is not yet supported together with the 2-level PHY priority.**

**Observation 2 The usefulness of PUCCH carrier switching highly depends on the underlying conditions to support the feature.**

**Observation 3 Support that HARQ-ACK corresponding to PDSCH received on a Pcell/PScell in a PUCCH group, can be sent on a PUCCH on an Scell in the same PUCCH group.**

**Observation 4 Operation of PUCCH carrier switching in a PUCCH group should not be conditioned on the numerologies in the PUCCH group, such that UL SCS can be same or larger/smaller than DL SCS.**

**Observation 5 Operation of PUCCH carrier switching in a PUCCH group should be under gNB control.**

**Observation 6 Operation of PUCCH carrier switching should be based on extension of existing PUCCH related procedures to more carriers in the PUCCH group.**

**Observation 7 If the gNB indicates a cell for PUCCH by DCI, other factors such as UCI multiplexing or PUCCH resource or payload size, etc. should not result in further changes of the cell for PUCCH.**

**Observation 8 Discussion are needed to understand joint operation of PUCCH carrier switching and simultaneous PUCCH/PUSCH transmission, as well as extension of simultaneous UL transmissions to simultaneous PUCCHs transmission on multiple carriers.**

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

**Proposal 1 Discussions on Type-3 HARQ-ACK codebook should prioritize “enabling” the feature for two-level priority transmission, rather than “enhancement of the codebook size”.**

**Proposal 2 Support triggering Type 3 HARQ-ACK codebook by DCI format 1\_2 with or without scheduling a PDSCH.**

**Proposal 3 Support priority indication in a DCI that triggers a Type 3 HARQ-ACK codebook.**

**Proposal 4 An indicated priority in a DCI that triggers a Type-3 HARQ-ACK codebook, determines the associated PUCCH\_Config for the corresponding PUCCH carrying the Type-3 HARQ-ACK codebook.**

**Proposal 5 A Type 3 HARQ-ACK codebook can include both HP and LP HARQ-ACK bit.**

**Proposal 6 For construction of a Type-3 HARQ-ACK codebook, activated cells are considered rather than configured cells.**

**Proposal 7 Support PUCCH carrier switching in a PUCCH group based on at least the following conditions:**

**• HARQ-ACK corresponding to PDSCH received on a Pcell/PScell in the PUCCH group, can be sent on a PUCCH on an Scell in the same PUCCH group.**

**• No restriction to the relation between the numerologies in the PUCCH group**

**• The PUCCH cell index in the PUCCH group is indicated by DCI and/or determined based on a configured pattern.**

**Proposal 8 Design of PUCCH carrier switching should be based on extension of existing PUCCH related procedures. An indicated PUCCH carrier for a UCI transmission should not be changed further for the UCI transmission.**

**Proposal 9 Discuss joint operation of PUCCH carrier switching and simultaneous PUCCH/PUSCH transmission, and the extension of UL transmissions to simultaneous PUCCHs transmission.**

### R1-2104262 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon

***Proposal 1: Support PUCCH carrier switching in Rel-17.***

***Proposal 2：Dynamic PUCCH carrier switching with the DCI to indicate the carrier for PUCCH transmission should be supported in Rel-17 for HARQ-ACK feedback.***

* ***A predefined rule can be used for further determining the carrier for PUCCH transmission in case of SPS PDSCH HARQ-ACK feedback.***

***Proposal 3：If Type 3 CB(s) with smaller size (compared to Rel-16) is to be supported in Rel-17,***

* ***The codebook size is determined by RRC configuration.***
* ***The codebook construction uses HARQ processes as a bases.***

### R1-2104309 HARQ-ACK Feedback Enhancements for URLLC/IIoT Nokia, Nokia Shanghai Bell

The discussions **in Sec. 2 on retransmissions of dropped HARQ-ACK** can be summarized in the following related observations and proposals:

***Observation 2.1: 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 2.1: Support enhanced Type 3 CB(s) with smaller size (compared to Rel-16)**

* *Definition of enhanced Type 3 CB:* 
  + - *The codebook size of a single triggered enhanced Type 3 HARQ-ACK codebook is ~~not flexible, but~~ at least determined by RRC configuration*
    - *The codebook construction uses HARQ processes as a basis (i.e. ordered according to HARQ-IDs and serving cells)*

**Proposal 2.2: For Type 3 codebook enhancements for URLLC, RAN 1 to consider**

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

**Proposal 2.3: On one-shot HARQ-ACK codebook re-transmission on PUCCH and/or PUSCH:**

* **Support one-shot HARQ-ACK codebook re-transmission on PUCCH with a dynamic indication of the timing of the HARQ-ACK CB (of a specific PUCCH occasion) to be re-transmitted.**
* **Support dynamic triggering the retransmission of dropped HARQ-ACK on PUSCH via DCI scheduling the PUSCH retransmission.**
* **Further study autonomous HARQ-ACK re-transmission on PUSCH with a scheduled PUSCH re-transmission and via semi-static configuration for autonomous CG PUSCH re-transmission.**

The discussions **in Sec. 3 on dynamic PUCCH carrier switching** can be summarized in the following related observations and proposals:

***Observation 3.1: Changes of the PUCCH cell within a PUCCH repetition bundle with different associated SCS would require specific handling for all PUCCH switching alternatives.***

***Observation 3.2: Mixed numerology of PUCCH carriers for PUCCH carrier switching creates at least the following complications:***

* ***For Alt. 1, the multiplexing of SPS HARQ-ACK and DG PDSCH HARQ-ACK in terms of k1 definition (i.e. Type 1 CB) and related multiplexing. Overlapping PUCCHs for DG HARQ-ACK on lower SCS Scell with SPS HARQ-ACK on higher SCS PCell would require special handling.***
* ***For. Alt. 2B, the PUCCH slot/sub-slot selection for higher SCS cells, multiplexing handling for lower SCS cells as well as overall PUCCH carrier selection depending on the SCS of different PUCCH carriers. Multiple overlapping PUCCHs of different SCS PUCCH cells originating from different PUCCH slots/sub-slots of the target cell would need to be specifically handled.***
* ***For. Alt. 1A, the complications of both Alt. 1 and Alt. 2B apply.***
* ***For Alt. 2C, at least some rules for the PUCCH slot/sub-slot selection for higher SCS cells (as for Alt. 2B) would be needed.***

**Proposal 3.1: Limit the further discussions on the potential support of PUCCH carrier switching in Rel-17 to the case of same numerology (i.e. SCS) of the involved PUCCH candidate cells.**

**Proposal 3.2: If PUCCH carrier switching is to be supported, the PUCCH carrier switching should be limited to HARQ-ACK and SR only (i.e. PUCCH carrier switching for CSI is not to be supported).**

***Observation 3.3: PUCCH carrier switching for SR would be simple with Alt. 2C, could require common PUCCH configurations for PUCCH cells with Alt. 1A and 2B, and is possible only in presence of dynamically scheduled PUCCH with Alt. 1.***

***Observation 3.4: Alt. 1A and 2B are complex to specify and implement as well as complex to operate from gNB perspective as there is little to no control over the PUCCH carrier selection.***

**Proposal 3.3: Exclude Alt. 1A and 2B from the studies on PUCCH carrier switching for HARQ-ACK feedback and focus the further discussions on the remaining Alt. 1 (dynamic indication in DCI) and Alt. 2C (RRC configured PUCCH cell timing pattern).**

* **Nokia has a slight preference towards Alt. 2C due to the lower DL control signaling overhead and better handling for configured PUCCH (for SPS HARQ-ACK and/or SR).**

### R1-2104326 Discussion on HARQ-ACK enhancements for eURLLC ZTE

***Proposal 1:*** *The standardization work for retransmission of the low-priority HARQ-ACK codebook should be considered first.*

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

***Proposal 2:*** *The cancelled HARQ-ACK codebook should be triggered for transmission as early as possible after the conflict is determined, for example, the earliest trigger is started after the PDCCH corresponding to the high-priority PUCCH.*

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

***Observation:*** *Compared with Alt. 3/Alt. 4(DCI scheduling PUSCH or PUCCH to carry dropped HARQ), in order to support Alt. 2 (Type 3 CB), more issues need to be solved, which significantly increases the standardization work load.*

***Proposal 4:*** *For the retransmission 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 5:*** *Dynamic PUCCH carrier switching should be supported in HARQ-ACK enhancement in Rel-17 URLLC.*

***Proposal 6:*** *For dynamic PUCCH carrier switching in the PUCCH cell group, dynamic indication in DCI should be supported.*

* *PRI is used to instruct PUCCH carrier switching from an extended PUCCH resource set, which can include PUCCH resources of different UL CCs in the PUCCH cell group.*

***Proposal 7:*** *The PUCCH resource and PUCCH carrier are always determined using k1 and PRI from the DCI according to the SCS corresponding to each carrier in a PUCCH cell group.*

***Proposal 8:*** *Configure a cell set to support PUCCH carrier switching among cells in the cell set.*

***Proposal 9:*** *In Rel-17, PUCCH carrier switching should be supported first for scheduled PUCCH with HARQ-ACK and the discussion for configured PUCCH should be postponed.*

### R1-2104353 HARQ-ACK enahncements for Rel-17 URLLC vivo

**Proposal 1: Unified method(s) is supported for retransmission of cancelled HARQ-ACK for low priority and high priority.**

**Proposal 2: HARQ-ACK retransmission mechanisms introduced in NR-U Rel-16 should be a starting point, and there is no need to introduce additional ones.**

**Proposal 3: Support the retransmission of cancelled HARQ-ACK by enhancing the Type-3 codebook.**

**Proposal 4: Support the retransmission of cancelled HARQ-ACK by Type-2 codebook with clarification that PDSCH grouping is within each priority with maximum two PDSCH groups per priority.**

**Observation 1: The plan for realistic deployment scenarios including TDD configurations for PUCCH carrier switching have not been identified.**

**Observation 2: Compared to existing mechanisms, e.g. configuring the balanced DL-UL or UL heavy TDD carrier as the PUCCH carrier, configuring two PUCCH cell groups, or multiplexing the UCI on PUSCH in SCell, etc., the additional performance benefits by PUCCH carrier switching have not been identified.**

**Observation 3: To support PUCCH carrier switching, a lot of issues need to be addressed and large specification efforts are expected.**

**Proposal 5: Do not support PUCCH carrier switching for HARQ-ACK for URLLC Rel-17.**

### R1-2104420 Discussion on HARQ-ACK feedback enhancements for Rel-17 URLLC Spreadtrum Communications

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

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

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

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

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

**Proposal 6. Support enhancement type3 codebook for retransmission of cancelled HARQ.**

**Proposal 7. Regarding how to how to indicate an enhanced Type 3 CB to the UE, using dynamic indication in the DCI is supported (Option 3).**

**Proposal 8. With respect to the enhanced Type 3 CB triggering DCI issue, Option 1 (triggering DCI can scheduled PDSCH at the same time) is supported as a baseline.**

**Proposal 9. If a DCI is received to trigger type 3 codebook transmission, all configured HARQ-ACK process should be included regardless of the previous priorities.**

**Proposal 10. NACK skipping should be supported, and it can be applied by both skipped and non-skipped SPS PDSCH.**

**Proposal 11. NACK skipping scheme can be configured by higher layer signalling for all configured SPSs.**

**Proposal 12. ACK skipping scheme can be considered for SPS HARQ payload size reduction of non-skipped SPS PDSCH.**

**Proposal 13. For Type-1 HARQ-ACK codebook for sub-slot based PUCCH configuration, support PDSCH TDRA grouping per sub-slot.**

### R1-2104512 UE feedback enhancements for HARQ-ACK CATT

***Proposal 1: Enhanced Type-3 codebook which includes HARQ-ACKs for HARQ processes of SPS PDSCHs only is supported.***

***Proposal 2: Type-3 codebook and enhanced Type-3 codebook are distinguished by RRC configuration only.***

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

***Proposal 4: An additional DCI field can be added in DCI format 1\_2 to trigger (enhanced) Type-3 codebook.***

***Proposal 5: If one-shot triggering of dropped HARQ-ACK is supported, the offset between the slot for triggering DCI and slot for dropped HARQ-ACK can be indicated by the triggering DCI to identify which ‘dropped HARQ-ACK’ should be re-transmitted.***

***Proposal 6: PUCCH carrier switching based on dynamic indication in DCI is supported.***

* ***The transmission carrier of dynamic HARQ-ACK is indicated by DCI corresponding to the dynamic HARQ-ACK;***
* ***SPS HARQ-ACK can be multiplexed with dynamic HARQ-ACK in the same slot if dynamic HARQ-ACK is indicated to be transmitted on the switched cell and the other configured PUCCH resources can be dropped if they are in the same slot with the switched dynamic HARQ-ACK;*** 
  + ***For the case of different numerologies, the slot based the smallest SCS can be used as the reference slot.***

### R1-2104604 Discussion on UE feeback enhancements for HARQ-ACK CMCC

**Proposal 1: support PUCCH carrier switching in Rel-17.**

**Proposal 2: PUCCH carrier switching is based on dynamic indication in DCI.**

**Proposal 3: PUCCH carrier switching is based on RRC configured PUCCH cell timing pattern of applicable PUCCH cells, as a complementary method.**

### R1-2104663 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated

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

***Observation 1: The scenario of cancelling PUSCH and piggybacked HARQ bits is a strong case in URLLC scenarios.***

***Observation 2: The scenario of the UE internally dropping/cancelling LP PUCCH due to own HP PUCCH although theoretically possible should not be the driver for the work for cancelled/dropped HARQ bits in URLLC.***

***Observation 3: The work in specifying solutions for the scenario of SPS PUCCH HARQ bits colliding with DL symbols was initiated without any direct reference to any URLLC/IIOT scenario among the ones of TS 22.104.***

***Observation 4: The work in specifying modifications of Type 1 CB HARQ so as to support the feature of cancelled HARQ bits will be high.***

***Observation 5: The work in specifying modifications of Type 2 CB HARQ so as to support the feature of cancelled HARQ bits will be high.***

***Observation 6: PUCCH carrier switch for HARQ-ACK is beneficial to reduce HARQ-ACK feedback latency, especially for inter-band CA with unaligned SFN, which is already supported and standardized in Rel-16.***

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

***Proposal 1: Support enhancement for cancelled HARQ in URLLC; retransmission of cancelled HARQ bits constitutes solid use cases in IIOT scenarios.***

***Proposal 2: The main solution for (re)transmission of cancelled HARQ bits should be a network controlled mechanism. The network should indicate to the UE***

* ***the HARQ feedback bits for requested HARQ processes***
* ***the PUCCH resource used to carry the HARQ feedback bits for requested HARQ processes.***

***Proposal 3: Support transmission of canceled HARQ via 1-shot enhanced Type 3 CB. Rel. 17 Enhanced Type 3 CB, although different from Rel. 16 Type 3 CB, is constructed with the same principle where the Rel. 17 enhancement lies in the flexibility/reconfiguration of the Type 3 CB size and its contents:***

* ***Type 3 CB size per CC and number of reported CCs reconfigurable per CC***
* ***Type 3 CB HARQ bits only for indicated HARQ processes per CC.***

***Proposal 4: Rel. 17 Enhanced Type 3 CB does not require support of Rel. 16 Type 3 CB and both features can be activated/deactivated separately. An extra bit on the DCI (different from*** *pdsch-HARQ-ACK-OneShotFeedback****) activates/deactivates the Rel. 17 Enhanced Type 3 CB.***

***Proposal 5: Request for Rel. 17 Enhanced Type 3 CB issued via DCI 1\_1 (similar to Release 16 CB) via appropriate setting of the “Release 17 OneShotFeedback”. Request for:***

***Option 1: A/N bits for HARQ Process IDs indicated in the DCI***

***Option 2: A/N bits within a pre-determined time duration, td, with a starting point in time t0, e.g. t0: X sub(slots) prior to DCI.***

***Proposal 6: Enhanced Type 3 CB consisted of either***

***Option 1 (corresponding to Option 1 of proposal 5): (Latest) Bit per requested HARQ Process ID***

***Option 2 (corresponding to Option 2 of proposal 5): Bits per requested HARQ Process IDs within indicated time window.***

***Proposal 7: Only one Enhanced Type 3 CB size should be supported at a given time.***

***Proposal 8: Do not support request for retransmission of cancelled HARQ bits via PUSCH allocation.***

***Proposal 9: Do not support introduction of priority indication in the enhanced Type 3 CB.***

***Proposal 10: Request for Enhanced Type 3 CB can be issued as a response to***

***A) SPS PUCCH HARQ collision with DL symbols or with semi-static SSB symbols***

***B) Canceled HARQ bits***

***C) Both SPS PUCCH HARQ and Canceled HARQ bits***

***In case A, only HARQ Processes associated with SPS PDSCH are requested by the gNB and reported by the UE.***

***In cases B and C, HARQ processes associated with both SPS and DG PDSCHs are requested by the gNB and reported by the UE***

***An identifier in the DCI 1\_1 indicates the case for which Rel. 17 Enhanced Type 3 CB is issued.***

***Proposal 11: Support automatic transmission of cancelled HARQ ACK info at retransmission of PUSCH cancelled by DCI 2\_4.***

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

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

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

***Proposal 12: Do not support partial automatic (re)transmission of cancelled HARQ bits.***

***Proposal 13: Support joint configuration of Enhanced Type 3 CB and automatic reTx of canceled HARQ bits.***

***Proposal 14: Upon joint configuration of i) automatic transmission of cancelled HARQ bits and of ii) enhanced Type 3 CB, canceled HARQ bits transmission occurs with earliest opportunity - either with automatic retransmission via PUSCH, or via Enhanced Type 3 CB.***

***Proposal 15: 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 16: 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 17: PUCCH carrier switch is supported for UL CA with different SCS cross CCs. Within the reference slot (based on PCC numerology) indicated by K1, if multiple actual slots on a determined CC can be used to transmit the PUCCH, the earliest slot is selected.***

***Proposal 18: PUCCH carrier switch is configured by RRC per CC.***

***Proposal 19: With PUCCH carrier switch, do not support PUCCH resource sharing between dynamic PUCCH resource (indicated by PRI in DCI) and configured PUCCH resource (by RRC).***

***Proposal 20: With PUCCH carrier switch, the PUCCH resources are configured per CC.***

***Proposal 21: If enabled (by RRC configuration), PUCCH carrier switch is perform by UE before UCI multiplexing procedure or PUCCH/PUSCH simultaneous transmission.***

***Proposal 22: Simplify the PUCCH carrier switch by restricting to only one additional SCC to transmit PUCCH. UE interpret the K1 and PRI (or RRC configured PUCCH resource indicator for SPS A/N) twice, once for PCC and once for a configured PUCCH allowed SCC. Between the two interpretations, the interpretation for PCC takes precedence.***

### R1-2104802 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO

***Proposal 1: The following enhancements can be supported to reduce the payload of Type 3 HARQ-ACK codebook:***

* ***Multiple subsets of cells can be semi-statically configured by high layer signaling, and DCI indicates one subset for HARQ-ACK feedback.***
* ***Enhanced Type 3 CB includes the HARQ-ACKs corresponding to the DL HARQs within a predefined window which references to the reception of DCI.***

***Proposal 2: One-shot triggering of dropped HARQ-ACK should be supported.***

***Proposal 3: Dynamic indication of the PUCCH occasion that is to be retransmitted should be supported.***

***Proposal 4: If PUCCH carrier switching is to be supported, only a simple solution to determine PUCCH carrier can be considered.***

### R1-2104854 Discussion on two aspects of UE HARQ-ACK feedback enhancements China Telecom

**Proposal 1: PUCCH carrier switching for HARQ feedback is supported in Rel-17 URLLC.**

**Proposal 2: If DCI indicating the PUCCH carrier for HARQ-ACK transmission is supported in Rel-17,**

* **The reference SCS of PDSCH to HARQ-ACK offset K1 is the SCS of the indicated target carrier.**
* **RRC signal could configure different K1 sets for carrier with different SCS. The number of K1 values in the K1 sets should be the same.**
* **When the HARQ-ACK codebook only contains the SPS HARQ-ACK feedback, PDSCH MAC CE indicating the PUCCH carrier for HARQ-ACK can be considered if there is ACK in the codebook, PUCCH is dropped if all of the HARQ-ACK for these SPS PDSCH are NACK.**

**Proposal 3: If PUCCH carrier switching based on certain rules is supported in Rel-17,**

* **On the original carrier, a collision with semi-static DL symbols, SSB and CORESET#0 is regarded as needing carrier switching.**
* **For searching of the target carrier, firstly consider the carrier with PUCCH resource consisted of only semi-static UL symbols. If no target carrier is found, then semi-static flexible symbol can be used as the valid PUCCH resource.**
* **The carrier with larger SCS is ordered with priority.**
* **On the target carrier, available PUCCH resource is searched in the slot(s)/sub-slot(s) overlapped with the slot/sub-slot determined by K1 on the original PUCCH carrier.**

**Proposal 4: If PUCCH carrier switching based on RRC configured PUCCH cell timing pattern is supported in Rel-17,**

* **RRC configures a time unit and a period with the smallest SCS of the candidate PUCCH carriers as the reference SCS. The carrier configured for the time unit containing the slot/sub-slot determined by K1 is used for PUCCH transmission.**

**Proposal 5: Support enhanced Type 3 CB with reduced size. The enhanced Type 3 CB has a single size such as only include HARQ-ACK for active carriers in the PUCCH group and active SPS configurations, and is enabled by RRC.**

**Proposal 6: Support DCI format 1\_2 to trigger Type 3 HARQ-ACK CB transmission.**

### R1-2104899 On dynamic carrier switching and dropped HARQ feedback retransmission Intel Corporation

**Proposal 1-1**

* *Support enhanced Type 3 CB with a smaller size comparing to Release 16 Type 3 CB*
  + *Switching between Release 16 and Release 17 Type 3 CBs is based on RRC configuration*

**Proposal 1-2**

* *Support triggering of enhanced Type 3 CB transmission by both*
  + *DCI scheduling other PDSCH*
  + *DCI not scheduling other PDSCH*

**Proposal 1-3**

* *Support combination of RRC configuration and triggering DCI content for constructing enhanced Type 3 CB, i.e. support multiple Type 3 CB sizes*
  + *The different CB sizes are resulted from different assumption on*
    - *cells to be reported*
    - *SPS-only or all HARQ processes*
    - *priority*
    - *etc.*

**Proposal 1-4**

* *Support enhanced Type 3 CB construction from a subset of HARQ processes based dynamic indication in DCI triggering the enhanced Type 3 CB*
  + *The sub-set may comprise of the HARQ processes belonging to one or both priorities, if priority field in DCI is present, FFS details*

**Proposal 1-5**

* *If supported, the one-shot triggering of dropped HARQ feedback retransmission is indicated in the DCI scheduling PDSCH for which UCI carrying HARQ feedback may be subject to dropping*
  + *A substitute PUCCH resource is provided together with the original PUCCH resource, and is used whenever the original PUCCH resource is dropped, FFS details*

**Proposal 2-1**

* *If dynamic PUCCH carrier switching is supported, for PUCCH carrying HARQ feedback for SPS PDSCH, support RRC configuration of a time pattern indicating which carrier is used for PUCCH mapping when SPS PDSCH is received in that time slot indicated by the pattern*

**Proposal 2-2**

* *If dynamic PUCCH carrier switching is supported, for PUCCH carrying HARQ feedback for dynamic PDSCH, down select between*
  + *(1st preference) Dynamic indication of PUCCH carrier in DCI*
  + *(2nd preference) RRC configuration of a time pattern indicating which carrier is used for PUCCH mapping when a DCI is received in that time slot indicated by the pattern*

**Proposal 2-3**

* *If dynamic PUCCH carrier switching is supported, allow different sub-carrier spacing between PUCCH cells which are subject to switching, FFS details*

### R1-2105097 Views on eIIoT/URLLC HARQ feedback enhancements Apple

**Proposal 2-1: to control feedback overhead, the presence of NDI and utilization of CBG based feedback can be separately configured for code states in the “priority indicator”.**

**Proposal 2-2: to control feedback overhead, HARQ process IDs can be grouped, one group is associated with the high priority, another is associated with the low priority.**

**Proposal 3: study the UE behavior when SPS HARQ skipping and HARQ retransmission are both enabled.**

**Proposal 4: dynamic PUCCH carrier switching is excluded from further consideration.**

### R1-2105160 Retransmission of dropped HARQ-ACK for URLLC Sony

**Observation 1: Since the size of Type 3 HARQ-ACK Codebook is semi-static, any enhancement made to Type 3 HARQ-ACK Codebook for overhead reduction can never be as effective as a new HARQ-ACK codebook that retransmits only dropped HARQ-ACK.**

We therefore propose the following:

**Proposal 1: Do not support enhancements for Type 3 HARQ-ACK Codebook.**

**Proposal 2: Consider introducing one shot trigger for Type 3 Codebook in DCI Format 1\_2.**

**Proposal 3: Consider a new “one-shot trigger” to trigger a new Type 4 HARQ-ACK Codebook to retransmit only dropped HARQ-ACK(s), where this “one-shot trigger” can be transmitted using a DL Grant that can schedule a PUCCH without a PDSCH and/or an UL Grant that can schedule a PUSCH without any uplink data.**

**Proposal 4: Further consider the following 3 options on the definition of “dropped HARQ-ACK” under the context of HARQ-ACK retransmission:**

* **Option 1: the last dropped PUCCH occasion is to be re-transmitted**
* **Option 2: dynamic indication of the PUCCH occasion that is to be re-transmitted**
* **Option 3: based on a timing window of the PUCCH occasion(s) that is/are to be re-transmitted**

### R1-2105188 Discussion on UE feedback enhancements for HARQ-ACK PANASONIC R&D Center Germany

**Proposal 1: Consider only Alt. 1 for dynamic PUCCH carrier switching in Rel. 17.**

**Proposal 2: PUCCH carrier should be identified through the PRI filed. To enlarge PRI field should be considered. Proposal 3: A gNB should restrict the dynamic DCIs to point to the same PUCCH carrier for a given codebook construction.**

**Proposal 4: Support different SCSs for PUCCH carriers within a PUCCH cell group.**

**Proposal 5: The SCS of the target PUCCH carrier is considered for determining the timing of the PUCCH resource.**

**Proposal 6: To support PUCCH carriers with different SCSs, the RRC signaling is used with one of the following options.**

* **Option 1: A set of offset values are defined for different SCSs**
* **Option 2: Different sets of k1 values are defined for different SCSs**
* **Option 3: Different sets of k1 values are defined for different PUCCH carriers**

**Proposal 7: If retransmission of cancelled HARQ is supported, reuse the HARQ feedback based on Type-3 HARQ-ACK codebook.**

**Proposal 8: The codebook size of triggered Type-3 HARQ-ACK codebook should be determined by RRC configuration and activation.**

### R1-2105212 UE feedback enhancements for HARQ-ACK ETRI

Regarding PUCCH carrier switching,

**Proposal 1: If PUCCH carrier switching is supported, then the RRC configured approach is adopted, and further consider dynamic switching is discussed.**

**Proposal 2: Any UCI type can support the PUCCH carrier switching if supported.**

Regarding Type-3 HARQ-ACK codebook,

**Proposal 3: The size of the enhanced Type-3 HARQ-ACK codebook can be determined by at least activation/release DCI.**

**Proposal 4: The size of the enhanced Type-3 HARQ-ACK codebook can be determined by at least activated serving cells.**

**Proposal 5: The reference time to derive HARQ-ACK codebook is introduced in terms of a (sub) slot, where the HARQ-ACK of relevant HARQ processes are involved.**

**Proposal 6: If M=2 type-3 HARQ-ACK codebooks are enabled, then the distinct RNTI can be used to generate a legacy one or an enhancement one.**

### R1-2105258 UE feedback enhancements for HARQ-ACK NEC

**Proposal 1:**

* *Support more than one enhanced Type-3 HARQ-ACK codebook in Rel-17.*

**Proposal 2:**

* *Support dynamic triggering of a Type-3 CB 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 configured CC(s).*
    - *Alt.2: The requested HARQ-ACK codebook contains only the number of DL HARQ processes for the indicated SPS configuration(s) in the configured CC(s).*
    - *Alt.3: The requested HARQ-ACK codebook contains a set of DL HARQ processes for the configured/activated SPS configuration(s) in the configured CC(s).*

**Proposal 3:**

* *Further study the PUCCH resource determination for the triggered Type-3 HARQ-ACK codebook for SPS PDSCH only if supported.*

**Proposal 4：**

* *Support PUCCH carrier switching for HARQ-ACK feedback in Rel-17.*
  + *A predefined rule can be used for determining the UL carrier for PUCCH transmission.*

**Proposal 5：**

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

### R1-2105302 HARQ-ACK Reporting Enhancements for URLLC Samsung

This contribution considered aspects related to retransmission of HARQ-ACK information and to cell switching for UL transmissions and proposes the following.

**Proposal 1: Support triggering retransmission of a dropped HARQ-ACK codebook.**

**Proposal 2: Support cell switching for a PUCCH transmission based on (a) DCI indication and (b) a timing pattern provided by higher layers.**

**Proposal 3: Support cell switching at least for HP PUCCH with HARQ-ACK or SR.**

In addition, the following are observed.

**Observation 1**: Modifications of the Rel-16 Type-3 HARQ-ACK codebook are neither relevant nor necessary to support retransmission of HARQ-ACK information for Rel-17 URLLC.

**Observation 2**: Modifications of the Rel-16 Type-3 HARQ-ACK codebook are not likely to offer meaningful functional enhancements over the Rel-16 Type-3 HARQ-ACK codebook and would always be worse than retransmitting only the intended/dropped HARQ-ACK information.

**Observation 3**: Triggering HARQ-ACK retransmission in a PUCCH or PUSCH has minimal specification impact and practically no impact on UE complexity.

**Observation 4**: The enhanced Type-2 HARQ-ACK codebook is less flexible than retransmitting dropped HARQ-ACK information and is not generally feasible for non-shared spectrum operation in Rel-17 without additional enhancements.

**Observation 5**: Alternatives relying on a predetermined rule to determine a cell of PUCCH transmission have large specification and network/UE implementation impacts and can lead to problematic functionality.

**Observation 6**: Alternatives relying on the network to determine the cell of PUCCH transmission minimize specification impact and UE complexity while allowing full flexibility to the network and improving overall functionality.

### R1-2105399 HARQ feedback enhancements for IIoT and URLLC InterDigital, Inc.

**Proposal 1: The UE can retransmit a cancelled HARQ using Type 3 HARQ CB.**

**Proposal 2: Support enhanced Type 3 HARQ CB containing the same priority ACK/NACK feedback.**

**Proposal 3: The DCI triggering enhanced Type 3 CB can indicate the priority of the Type 3 HARQ CB.**

**Proposal 4: The PUCCH carrier switching is based on dynamic indication using the scheduling DCI.**

### R1-2105425 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics

Proposal 1: If there is a consensus that dynamic PUCCH carrier switching is necessary, PUCCH carrier switching based on dynamic indication in DCI can be supported

* To indicate switched carrier, a DCI field is added to DL scheduling DCI.
* If there are overlapping PUCCHs with the PUCCH indicated with carrier indication, overlapping PUCCHs are multiplexed and transmitted in switched PUCCH carrier by the indication.

Proposal 2: For HARQ-ACK PUCCH for SPS PDSCH itself, dynamic PUCCH carrier switching is not supported.

* Carrier indication in activation DCI is ignored for SPS PDSCH without corresponding DCI

Proposal 3: For dynamic PUCCH carrier switching from source carrier to target carrier, target carrier should be same or higher SCS than of source carrier.

Proposal 4: Support enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size for re-transmission of cancelled HARQ-ACK if necessary.

Proposal 5: For construction of the enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size, following options can be considered:

* Option 1: type-3 HARQ-ACK codebook with subset of entire HARQ processes.
  + Multiple subset of HARQ processes can be configured by RRC signaling.
  + A subset of HARQ processes can be indicated in a DCI triggering type-3 HARQ-ACK codebook for HARQ-ACK codebook construction.
* Option 2: type-3 HARQ-ACK codebook with HARQ processes used in SPS PDSCH reception.

Proposal 6: For triggering method enhanced type-3 HARQ-ACK codebook with reduced HARQ-ACK payload size, following options can be considered on the top of current framework. :

* + Option 1: triggering DCI indicates a subset of HARQ processes for the HARQ-ACK codebook. Existing DCI field (e.g., One-shot HARQ-ACK request field) can be re-used or extended for indicating a subset of HARQ process.
  + Option 2: RNTI scrambling CRC of DCI format can indicates how to construct type-3 HARQ-ACK codebook.

Proposal 7: For type-3 HARQ-ACK codebook only for SPS PDSCH, priority handling can be considered.

### R1-2105631 UE feedback enhancements for HARQ-ACK Sharp

**Proposal 1:**

* Rather than discussing on optimizations such as smaller codebook size, clarify the necessary modifications on Type-3 HARQ-ACK codebook for adoption in Rel-17 URLLC operation first, e.g., handling of different priorities.

### R1-2105693 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.

**Proposal 1: If DCI 1\_1 can be simultaneously configured with one-shot HARQ-ACK feedback and priority indicator field existing in DCI 1\_1, type 3 HARQ-ACK CB consists of all HARQ process IDs regardless of priority indicated for each HARQ-ACK bit. The priority of the HARQ-ACK PUCCH is determined by physical priority indicator in the triggering DCI.**

**Proposal 2: Support enhanced Type 3 CB(s) with smaller size,**

* **Option 1: HARQ-ACK information in the enhanced type 3 CB is determined based on RRC configured sub-set of HARQ processes and/or serving cells.**
* **Option 2: HARQ-ACK information in the enhanced type 3 CB is determined based on time window indicated by the triggering DCI.**

**Proposal 3: If enhanced type 3 CB with only HARQ-ACKs in a time window is not supported, support triggering HARQ-ACKs in a time window to be retransmitted on PUCCH.**

**Proposal 4: Support Alt 2B or Alt 2C for PUCCH carrier switching, at least for HARQ-ACK PUCCH.**

* **Same SCS candidate PUCCH Scells as SCS of PCell/PSCell/PUCCH-Scell is preferred.**
* **Same number of PUCCH-configs among candidate PUCCH Scells and PCell/PSCell/PUCCH-Scell is expected.**

### R1-2105732 On UE feedback enhancements for HARQ-ACK MediaTek Inc.

***Observation 1: Dynamic cross-carrier PUCCH allows for up to 30% latency reduction.***

***Observation 2: Dynamic cross-carrier PUCCH doubles the network capacity and reduces the resource utilization compared to the Carrier Aggregation baseline operation.***

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 retransmission of cancelled low priority and high priority HARQ.***
3. ***Support reusing the existing Rel-16 Type 3 HARQ-ACK codebook.***
4. ***Support the use of DCI scheduling new PUCCH / PUSCH resource for HARQ re-transmission / One-shot triggering of dropped HARQ-ACK.***

### R1-2105750 UE feedback enhancements for HARQ-ACK CAICT

In this contribution, we discussed more aspects about PUCCH carrier switching for HARQ feedback in Rel.17 URLLC. The following proposals are reached:

**Proposal 1: Support PUCCH carrier switching for HARQ feedback.**

**Proposal 2: To exclude Alt. 1A for further study.**

**Proposal 3: For Alt.1, PUCCH switching for SPS HARQ-ACK is achieved by dynamic PUCCH/PUSCH scheduling in another cell.**

**Proposal 4: For dynamic PUCCH carrier switching, implicit indication through PRI is used.**

**Proposal 5: Configure independent candidate K1 values for different SCSs.**

**Proposal 6: Alt. 2B is based on more consensus in terms of SPS HARQ-ACK deferral.**

**Proposal 7: Support Alt. 1 at this time.**

### R1-2105766 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility

**Proposal 1: Support autonomous one-shot HARQ-ACK re-transmission for all or a subset of HARQ processes in a CG-PUSCH resource, where the CG-PUSCH is available in an earlier slot/sub-slot than a slot/sub-slot with the earliest available PUCCH resource for HARQ-ACK.**

**Observation 1: 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.**

**Observation 2: UE should be able to perform dynamic PUCCH carrier switching without dynamic indication to enhance HARQ-ACK feedback consisting of only SPS PDSCH HARQ-ACK bits.**

**Proposal 2: Support dynamic PUCCH carrier switching based on semi-static rules (Alt 2B).**

### R1-2105819 Discussion on UE feedback enhancements for HARQ-ACK Asia Pacific Telecom, FGI

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

**Proposal 2 When the priority indicator indicates low priority and high priority, a PUCCH resource for the Type-3 HARQ-ACK codebook should be selected based on the payload size of the Type-3 HARQ-ACK codebook and the PRI in the triggering DCI, from the PUCCH resources configured in the first PUCCH-Config and in the second PUCCH-Config, respectively.**

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

**Proposal 4 A list of pdsch-HARQ-ACK-OneShotFeedbackNDI-r16 is used to indicate the presence of NDI bits in the Type-3 HARQ-ACK codebooks triggered by DCI formats indicating low priority and high priority.**

**Proposal 5 For PUCCH carrier switching, support of Alt.1A is preferred.**

### R1-2105872 Discussion on HARQ-ACK enhancement for URLLC/IIoT WILUS Inc.

**Proposal 1: Support one-shot triggering of enhanced Type-3 HARQ-ACK CB.**

** Further discuss how to configure/indicate HARQ process numbers.**

**Proposal 2: One-shot HARQ-ACK codebook is used for retransmission of cancelled HARQ-ACK information and the following aspects should be further enhanced.**

** Determination of Type-3 HARQ-ACK CB priority, Support of DCI format 1\_2 triggering Type-3 HARQ-ACK CB, and inclusion of HARQ-ACK associated with SPS release DCI.**

**Proposal 3: If dynamic PUCCH carrier switching is supported, Alt 2C is preferred in terms of PUCCH carrier ambiguity.**