**3GPP TSG-RAN WG1 Meeting #102-eR1-20XXXXX**

**e-Meeting, August 17th – 28th, 2020**

**Agenda item: 8.3.1.1**

**Source: Moderator (Nokia)**

**Title: Feature lead summary #2 on Rel-17 HARQ-ACK feedback enhancements for NR Rel-17 URLLC/IIoT (AI 8.3.1.1)**

**Document for: Discussion and Decision**

# 1 Introduction

As per chairman’s guidance, two rounds with check points below are planned.

[102-e-NR-IIOT\_URLLC\_enh-01] Email discussion/approval – Nokia (Klaus)

* By 8/21 – high priority
* By 8/27 – medium

This document is structured as follows:

* Section 2 contains the discussion input for each of the discussion phases which more guidance provided in each of the discussion steps (incl. potential intermediate steps)
* Sections 3 to 6 contain summary of the discussed issues / proposed enhancements in companies’ contributions

# 2 RAN1#102-e discussions on 8.3.1.1

## 2.1 First round of email discussions

*FL comment:*

Based on chairman’s guidance received at the end of the first Rel-17 URLLC/IIoT session on Tue Aug 18th, 2020, there is a need to identify the priorities of different issues to be discussed as there are many different enhancements proposed by companies in a lot of different directions. Which is aligned with the WID of the objective which clearly states “*Study, identify and specify if needed,….*”.

|  |
| --- |
| * Study, identify and specify if needed, required Physical Layer feedback enhancements for meeting URLLC requirements covering:   + UE feedback enhancements for HARQ-ACK [RAN1]   + CSI feedback enhancements to allow for more accurate MCS selection [RAN1]   + Note: DMRS-based CSI feedback is not in scope of this WI |

The task of identifying the ‘high priority / medium priority / low priority’ is clearly very tricky considering the vast number of different issues and proposals input to this meeting.

**Therefore, the following procedure (at least for the first round of email discussion) is proposed by FL:**

1. For issues to be solved supported by several contributions (>=5), there are direct questions if supporting some enhancements are to be considered with high priority in this section (Sec. 2.1). Moreover, discussion on the technical solutions proposed are then handled in the related subsections of Sec. 3 to Sec. 6 (input there could be provided still later on, if agreed to have those as high priority items). The issues brought up by more or equal than 5 contributions include:
   * Avoiding unnecessary SPS HARQ-ACK dropping for TDD (in Sec. 3.1)
   * SPS HARQ-Ack payload size reduction / skipping (Sec. 3.2)
   * SPS HARQ-ACK skipping for ‘skipped SPS PDSCH (Sec. 3.3)
   * Type 1 HARQ-ACK CB for sub-slot PUCCH (of Sec. 4.1)
   * ‘Sub-slot’ type of PUCCH repetition (Sec. 5.1)
   * Retransmission of Canceled / Dropped Low-priority HARQ-ACK (Sec. 6.1)
2. For the rest of the issues / solutions / schemes proposed by a small(er) number of contributions (i.e. 1 or 2 contributions), there are tables for each of the issues / solutions in the relevant subsections, where companies can provide their input on priority (high/medium/low) as well as some optional technical comments (which could be left to phase 2 as well,).
   * The FL summarize the interest of different companies later on in a single table in this subsection (i.e. how many companies suggesting high / medium / low)
   * So maybe the detailed technical discussion on these could be of lower priority for the moment (e.g. in a later phase) but your input on priority would be helpful for further discussions already now.
3. ***Please note, that it would be good to have some kind of understanding of the interest or importance of the different issues early (e.g. Thu, Aug 20th EOB). Therefore, at least provide your input the questions in this section (Questions 2.1.1 to 2.1.5) as well as ‘high / medium / low’ in the other sections not handled here early.*** 
   * Of course you can still add any technical comments at any point of time still later on – which includes the topics with so far large(r) company support (of Sec. 3.1, 3.2, 3.3, 4.1, 5.1 and 6.1) and especially any technical comments on the other issues in the remaining sub-sections of sections 3, 4, 5 & 6.

**Avoiding unnecessary SPS HARQ-ACK dropping for TDD (in Sec. 3.1)** in Rel-17 is discussed in 14 (out of 26) contributions. This may be a clear early indication that this issue is to be solved in Rel-17 and therefore may be considered as a high priority issue in Rel-17. As a consequence, the following question is put directly forward here:

**Question 2.1.1: Should avoiding SPS PDSCH HARQ-ACK dropping for TDD (discussed in Sec. 3.1) be considered with high priority in Rel-17? *Yes / No***

* **If *No*: please provide your suggested priority level (medium / low) and some related explanation / discussion as comments**

|  |  |  |
| --- | --- | --- |
| *Company* | *Yes / No* | *Comments* |
| Sony | Yes |  |
| Sharp | Yes |  |
| DOCOMO | Yes |  |
| CMCC | Yes | When the SPS periodicity is down to 1 slot, the collision between SPS HARQ-ACK and semi-static UL/DL configuration as well as dynamic SFI would happen frequently especially for DL heavy TDD frame structure. The feature of shorter SPS periodicity cannot work well without solving the collision issue. |
| vivo | Yes | This issue is deprioritized in Rel.16 due to limited time. We should solve it in Rel.17. |
| Xiaomi | Yes |  |
| CATT | Yes |  |
| Samsung | Yes | Always good to avoid dropping HARQ-ACK, especially when the probability is large – there is a whole A.I. 8.3.3 for eMBB - this is even for URLLC and the probability for dropping is much larger than for eMBB in 8.3.3. |
| ZTE | Yes |  |
| Intel | Yes |  |
| Panasonic | Yes |  |
| WILUS | Yes |  |
| NEC | Yes |  |
| Huawei, HiSilicon | Yes | Dropping the HARQ-ACK too frequently will result in low resource efficiency since re-transmission needed, and also have impact on URLLC latency |
| LG | Yes |  |
| InterDigital | Yes |  |
| Nokia, NSB | Yes |  |
| MediaTek | Yes |  |
| Apple | Yes |  |

**SPS HARQ-Ack payload size reduction / skipping (Sec. 3.2) and SPS HARQ-ACK skipping for ‘skipped SPS PDSCH (Sec. 3.3):** Based on Sec. 3.2, 5 contributions discuss SPS HARQ-ACK payload size reduction / skipping for SPS PDSCH in general, whereas 5 other contributions based on Sec. 3.3 discuss HARQ-ACK skipping for the case the SPS PDSCH is not valid (or not transmitted by the gNB, i.e. skipped). So overall, 10 (out of 26) contributions suggest handling SPS HARQ-ACK payload size / skipping for different use cases and reasons in Rel-17. Thus, the following question is put directly forward here:

**Question 2.1.2: Should SPS HARQ-ACK payload size reduction / skipping (based on Sec. 3.2 in general and/or 3.3 for ‘skipped’ SPS PDSCH) be considered with high priority in Rel-17? *Yes / No***

* **If *No*: please provide your suggested priority level (medium / low) and some related explanation / discussion as comments**

|  |  |  |
| --- | --- | --- |
| *Company* | *Yes / No* | *Comments* |
| Sony | No | The issue in 3.2 and 3.3 are different. 3.3 is only about skipping NACK due to skipped SPS whereas 3.2 is skipping HARQ-ACK in general. We are ok with issue in 3.3 but don’t think 3.2 should be high priority. |
| Sharp | Yes | We share the similar view with Sony that Sec. 3.2 and Sec. 3.3 should be treated separately here. We are OK to treat the issue in Sec. 3.3 with high priority. |
| DOCOMO | Yes |  |
| CMCC | 3.3 Yes  3.2 No | SPS HARQ-ACK skipping for ‘skipped SPS PDSCH **(Sec. 3.3): High priority**  SPS HARQ-Ack payload size reduction / skipping **(Sec. 3.2): Medium priority** |
| vivo | Yes, for 3.3  No, for 3.2 | In Rel.16, RAN2 agreed to support the TSC traffic with non-integer periodicity in terms of OFDM symbol granularity by over provision of the SPS for DL (and CG for UL) resources. Due to limited time, related enhancements e.g. HARQ-ACK skipping as summarized in section 3.3 should be done in Rel.17.  About section 3.2 on SPS HARQ-ACK payload size reduction / skipping for SPS PDSCH, we wondered whether the methods proposed there can also be applied to dynamic PDSCH? Seems the enhancements are not specific to SPS PDSCH. |
| Xiaomi | No | It seems that two cases are proposed by companies to justify the SPS HARQ-ACK skipping,  Case 1, SPS with short periodicity is configured for URLLC traffic, but the actual DL URLLC traffic is not periodical, which means some SPS PDSCHs are empty.  Case 2, multiple SPS PDSCH configuration to accommodate one TSC traffic.  For Case 1, our opinion is that dynamic scheduling is more suitable for non-periodical traffic. And skipping HARQ-ACK for SPS PDSCH may possibly lead to HARQ-ACK codebook misalignment between gNB and UE, which is harmful to URLLC traffic.  For Case 2, an example in R1-2005347 is listed, three SPS PDSCHs are configured for a TSN traffic has an arrival frequency of 120Hz, i.e., the periodicity is 8.333ms, thus a lot of PDSCHs are empty. From our point of view, similar as Case1, TSN traffic can be dynamic scheduled with high priority. And on the other hand, the problem of empty PDSCHs seems stemming from a bad configuration. If gNB configure 3 SPS PDSCHs as the following, then there would be no empty PDSCHs (assuming SCS=15KHz),  SPS PDSCH1(offset 0, Period 25ms)  SPS PDSCH2(offset 8ms+5symbol, Period 25ms)  SPS PDSCH3(offset 16ms+10symbol, Period 25ms) |
| CATT | No | Medium. Evaluation results are needed to justify the benefit for URLLC service. |
| Samsung | No | For RM coding (expected in such case), there is no benefit (even the PUCCH resource will probably be 1 RB).  For polar coding, any overhead reduction would be marginal and inconsequential. |
| ZTE | 3.2 No 3.3 Yes | SPS HARQ-Ack payload size reduction / skipping **(Sec. 3.2): Medium priority**  SPS HARQ-ACK skipping for ‘skipped SPS PDSCH **(Sec. 3.3): High priority** |
| Intel | No | Medium. We agree that the intention seems nice, but none of the proposed schemes have been shown to provide system gains at the expense of the specification efforts.  We see some rationale with skipping the PUCCH with all NACKs, but this may be an optimization in the system with > 1-bit codebook. |
| Panasonic | Yes for 3.3  No for 3.2 | NACK skipping for skipped PDSCH could be prioritized in Rel.17. |
| WILUS | No | Medium. We are ok to discuss SPS HARQ-ACK size reduction by applying e.g. simple bundling if needed, but ACK/NACK skipping results in large spec impacts especially on HARQ-ACK codebook design. |
| NEC | Yes |  |
| Huawei, HiSilicon | Yes | In our understanding, the mechanism for ACK skipping and NACK skipping is similar, thus it would be good to treat both the same level. |
| LG | Yes for 3.3  No for 3.2 | ACK skipping can be considered as high priority. |
| InterDigital | Yes |  |
| Nokia, NSB | Yes | SPS HARQ-ACK payload size reduction should be supported in general, not just for skipped PDSCH cases. So we support both – 3.2 and 3.3 with high priority. |
| MediaTek | No | Low |

**‘Sub-slot’ type of PUCCH repetition (Sec. 5.1):** There are still discussions in the Rel-16 maintenance, to which extend sub-slot PUCCH repetition is (to be) supported in Rel-16. Two contributions indicate that this is supported in Rel-16 (but propose related enhancements in Rel-17) and 5 companies discuss that the support is to be done in Rel-17 – which means that 7 (out of 26) contributions indicate their interest in related enhancements to handled in Rel-17. As a consequence, the following question is put directly forward here:

**Question 2.1.3: Should ‘Sub-slot’ Type of PUCCH repetition (or at least enhancements on top of Rel-16, see Sec. 5.12) be considered with high priority in Rel-17? *Yes / No***

* **If *No*: please provide your suggested priority level (medium / low) and some related explanation / discussion as comments**

|  |  |  |
| --- | --- | --- |
| *Company* | *Yes / No* | *Comments* |
| Sony | No | Medium. |
| Sharp | Yes | Sub-slot PUCCH repetition is one way to enhance the PUCCH reliability. |
| DOCOMO | Yes |  |
| CMCC | No | Medium.  URLLC feedback latency is mainly limited by semi-static UL/DL configuration especially worst latency is used as performance metric. So the benefit of sub-slot/mini-slot type of PUCCH repetition can be achieved by long PUCCH format when single TRP is configured. If some performance gain is observed for sub-slot/mini-slot PUCCH repetition in multi-TRP operation, we are open to further discuss this optimization.  Moreover, as discussed in our paper [15], low code rate for PUCCH can achieve lower latency comparing to sub-slot/mini-slot PUCCH repetition. It is observed that PUCCH is power unlimited in most cases, so support of lower effective code rate for PUCCH is a more effective way to enhance PUCCH reliability within a certain delay budget. |
| vivo | No | Low priority.  Firstly, Rel.16 is still discussing it and it is not clear to what extent the sub-slot PUCCH repetition will be supported. Without conclusion made in Rel.16, it is not sure what is the baseline to further enhance sub-slot PUCCH repetition.  Secondly, from latency and reliability perspective, the benefits of sub-slot PUCCH repetition is not clear compared to the Rel.15 long PUCCH transmissions. Learned from Rel.16 PUSCH repetition Type B, the specification impacts to support such sub-slot PUCCH repetition would be big. If companies consider using different spatial relations for different sub-slot PUCCH repetition to get the diversity gain, then it should be discussed in Rel.17 MIMO WI. |
| Xiaomi | Yes |  |
| CATT | No | Low. The motivation/benefit to support/enhance sub-slot based PUCCH repetition is not clear. |
| Samsung | Yes | High  It is not so much for sub-slot based repetition (this may already be supported) as it is for supporting repetition for PF0/PF2 in FR2. Coordinate with other WIs, especially the MIMO WI, to avoid possible duplications. |
| ZTE | Yes | The issue should be discussed, but maybe the solutions will be overlap with the solution for NR coverage enhancement. |
| Intel | Yes | The PUCCH repetitions should be considered with same motivation as PUSCH repetitions Type B – in order to improve latency-reliability tradeoff. We see at least the following use cases:   * Utilize most of the latency budget by allocating PUCCH to cross slot boundary * Employ diversity (e.g. FH) over PUCCH repetitions   Allow per-repetition dropping, thus increasing PUCCH delivery chances e.g. when collided with UL-DL direction or HP channel |
| Panasonic | Yes |  |
| WILUS | No | Low. For sub-slot configuration with 2 symbols, sub-slot PUCCH repetition seems to be short PUCCH repetition which is carefully studied. For sub-slot configuration with 7 symbols, the benefits of sub-slot PUCCH repetition over slot-based PUCCH repetition is not clear. |
| NEC | Yes |  |
| Huawei, HiSilicon | Yes | We don’t have any agreement yet that sub-slot PUCCH repetition is supported in Rel-16, just from the specification perspective it is happened to be supported to some extent. However, even there is common understanding that it is already supported in Rel-16, we think further enhancements in Rel-17 is needed to enable flexibility on the number of repetitions. |
| LG | No |  |
| InterDigital | Yes |  |
| Nokia, NSB | No | Low.  In Rel-16 it is still being discussed whether a 7 OS sub-slot configuration supports PUCCH repetitions of format 1,3,4 (long formats), and here it is our understanding that Rel-16 already does. We do not see the need to discuss sub-slot PUCCH repetitions for other formats or for other sub-slot configurations. |
| MediaTek | No | Low |

**Retransmission of Canceled / Dropped Low-priority HARQ-ACK (Sec. 6.1):** The negative impact of dropping / canceling low priority HARQ-ACK on the eMBB performance and the need for enabling re-transmissions of dropped LP HARQ-ACK is discussed in 9 (out of 26) contributions which may indicate an interest to consider this with high priority.

At the same time, there is a dedicated objective in this WI to support improved UCI multiplexing of different priorities, which could (if supported for LP HARQ-ACK) at least partially remove the motivation for enabling any type of later HARQ-ACK re-transmission.

**Question 2.1.4: Should retransmission of canceled / dropped low-priority HARQ-ACK (Sec. 6.1) be considered with high priority (Yes / No)? How do you see the relation to enhanced LP HARQ-ACK multiplexing on a high priority channel discussed in AI 8.3.3?**

* **If *No*: please provide your suggested priority level (medium / low) and some related explanation / discussion as comments**

|  |  |  |
| --- | --- | --- |
| *Company* | *Yes / No* | *Comments* |
| Sony | No | Low. Can be dealt with in AI 8.3.3 |
| Sharp | No | Medium.  HARQ-ACK multiplexing of different priorities on a single PUCCH can be supported with high priority under some timing conditions.  If multiplexing timing is not satisfied, LP HARQ-ACK is dropped, as in Rel-16. It is a desirable enhancement, but only happened under some timing constraints.  Thus, retransmission of LP HARQ-ACK can be treated with medium level. |
| DOCOMO | Yes |  |
| CMCC |  | **Retransmission of low-priority HARQ-ACK due to inter-UE cancelation: High priority**  **Retransmission of low-priority HARQ-ACK due to intra-UE prioritization: Low priority**  **For low-priority HARQ-ACK drop due to intra-UE prioritization, it is preferred to discuss in AI 8.3.3** to multiplex LP HARQ-ACK on HP PUCCH/PUSCH. So we think it can be treated as secondary priority.  For low-priority HARQ-ACK drop due to inter-UE cancelation, we think it should be treated as high priority since that for many UEs, DL and UL traffic are relatively symmetric, so HARQ-ACK is of high probability to be multiplexed on PUSCH especially for DL heavy TDD frame structure. In this case, low-priority HARQ-ACK drop due to inter-UE cancelation may happen frequently, which results in lots of unnecessary PDSCH retransmissions and decrease system spectral efficiency. |
| vivo | Yes | We think retransmission of cancelled / dropped low-priority HARQ-ACK and enhanced LP HARQ-ACK multiplexing on a high priority channel complement each other.  As analysed in our contribution, in some cases, to protect the HP channels, dropping LP HARQ-ACK would be better compared to multiplexing (e.g. due to timeline, payload size of LP HARQ-ACK etc); So, retransmission of cancelled / dropped low-priority HARQ-ACK can be used; For some other cases, multiplexing the LP HARQ-ACK with HP channels would be a better way. |
| Xiaomi | No | Medium.  If in 8.3.3 discussion, we finally determine that LP HARQ-ACK can not be multiplexed on a high priority channels, then maybe we can further discuss how to do the retransmission of LP HARQ-ACK. |
| CATT | No | Low. Enhanced LP HARQ-ACK multiplexing on a high priority channel discussed in AI 8.3.3 can mitigate the HARQ-ACK dropping. Further enhancements should be discussed after the discussion/conclusion in AI 8.3.3. In addition, it should be clarified how it helps to meet URLLC requirements. |
| Samsung | TBD | If HARQ-ACK can be viewed as a special case that falls under this AI, then ‘Yes’.  Else, it is related to 8.3.3 and can be addressed in that AI. See later comments. |
| ZTE | Yes | Retransmission of HARQ-ACK is very important to enhance the spectrum efficiency. |
| Intel |  | We are not sure if the moderator classified such features as one-shot HARQ-ACK or NNK1 as retransmission of the LP feedbacks.  If yes, then we see the discussion is required in this direction, and it is not limited to only retransmission of LP feedbacks only, but also to DL SPS collision cases.  If the meaning is different, then we are OK to deprioritize or handle as part of AI 8.3.3 |
| Panasonic | No | Medium  Although HARQ-ACK retransmission could be considered as one of potential techniques for improving the system efficiency, to multiplex the HARQ-ACK with different priorities into one PUCCH or PUSCH (AI 8.3.3) is more important. |
| WILUS | Yes | Our thinking is the enhanced multiplexing discussed in 8.3.3 is a way to transmit LP HARQ-ACK, but it may not be mandatory to all Rel-17 UEs. Also, applying Rel-17 enhanced multiplexing or Rel-16 prioritization can be configured by RRC or indicated by DCI (if supported). In this sense, we need to investigate how to re-transmit the dropped/cancelled HARQ-ACK information due to Rel-16 prioritization. |
| NEC | No | Medium.  We think whether this issue should be discussed depends on the result of collision case handling related low priority HARQ-ACK in AI 8.3.3. For the collision case between a PUCCH with low priority HARQ-ACK and another high priority PUCCH/PUSCH, if the low priority HARQ-ACK multiplexing on high priority PUCCH/PUSCH is allowed, no need to discuss the retransmission of dropped low-priority HARQ-ACK, otherwise, this issue can be discussed in AI 8.3.1.1 or AI 8.3.3. |
| Huawei, HiSilicon | No | Now we will specify the mechanism for multiplexing at least for intra-UE multiplexing, therefore dropping low priority HARQ-ACK may not happen so often. |
| LG | No | We have another AI to cover dropping due to higher priority. |
| InterDigital | Yes | We already have some existing mechanisms in Rel-16 that can be reused here. |
| Nokia, NSB | No | Medium (or even Low)  There will be reduced need for this (compared to Rel-17) if enhanced intra-UE multiplexing of different priorities is to be supported as part of AI 8.3.3 discussions. |
| MediaTek | Yes | We can’t assume multiplexing procedures in Rel-17 to be supported by all UEs. Retransmission of dropped HARQ is easier to implement from UE perspective.  Also, the multiplexing procedures in Rel-17 will be conditional, which mean dropping LP-HARQ will still occur. |

**Type 1 HARQ-ACK CB for sub-slot PUCCH (of Sec. 4.1):** There are still discussions in the Rel-16 maintenance to which Type 1 HARQ-ACK codebook could be supported in Rel-16 (not at all, or without any optimizations). But 6 contributions (of 26) discuss this to be at least supported (incl. optimizations of the HARQ-ACK payload) by the end of Rel-17 which indicates some interest to consider this in Rel-17 with high(er) priority. As a consequence, the following question is put directly forward here:

**Question 2.1.5: Should Type 1 HARQ-ACK codebook based on sub-slot PUCCH (see Sec. 4.1) be supported including payload size optimizations at least by the end of Rel-17 (if not supported in Rel-16) and therefore be considered with high priority? *Yes / No***

* **If *No*: please provide your suggested priority level (medium / low) and some related explanation / discussion as comments**

|  |  |  |
| --- | --- | --- |
| *Company* | *Yes / No* | *Comments* |
| Sony | No | Low. PDCCH for URLLC is reliable and traffic is sporadic. Type 1 CB is therefore not efficient. |
| Sharp | No | Low.  For URLLC, Type 2 HARQ-ACK codebook is more suitable and is already supported.  Type 1 HARQ-ACK codebook will result in unnecessary complexity, large HARQ-ACK payload size and poor PUCCH resource utilization. |
| DOCOMO | Yes |  |
| CMCC | Yes |  |
| vivo | No | Low priority.  It is obvious that the number of symbols for PUCCH using sub-slot is usually less than that for slot based PUCCH which has impacts on the supported UCI payloads and reliability, coverage etc. Type 1 HARQ-ACK codebook typically has large payload that contains many redundant bits. Therefore, it is not desirable to use Type 1 HARQ-ACK codebook for sub-slot PUCCH for URLLC. |
| Xiaomi | No | R16 already support subslot-based Type1 HARQ-ACK, even codebook size can be optimized in some degree. But Type 2 HARQ-ACK codebook, from our point, is a better solution and can already work well with subslot-based Type1 HARQ-ACK.  We can revisit this issue if time budget allows. |
| CATT | Yes |  |
| Samsung | No | Medium. It would be beneficial to support type-1 HARQ-ACK codebook for reliability for URLLC. It may require marginal specifications than currently available. It can be discussed if time allows. |
| ZTE | Yes | Rel-16 doesn’t support this function. And this function benefit is very clear through the long-time discussion. |
| Intel | No | Medium  In our understanding, Rel.16 does not support (or does not optimally support) Type 1 due to the complexity of balancing scheduling flexibility and the CB size. We think Type 2 CB can be adapted to any required robustness of the system.  It would be great to see more analysis on the benefits of Type 1 CB vs Type 2 CB |
| Panasonic | No | Low  For sub-slot-based operation, semi-static codebook could have larger overhead in the uplink. |
| WILUS | No | Low. The size of type-1 HARQ-ACK codebook can be controlled by gNB by configuring small number of K1 values or TDRA entries. Additionally, if the size is too high to provide sufficiently high reliability, gNB can configure type-2 HARQ-ACK codebook instead. |
| NEC | Yes | It is beneficial to support sub-slot based Type-1 HARQ-ACK codebook, since it is more robust than Type-2 HARQ-ACK codebook. Regarding the concern of the redundancy of the Type-1 HARQ-ACK codebook, on one hand, it can be controlled by gNB with configuring suitable K1 set and TDRA table, on the other hand, small enhancements on sub-slot Type-1 HARQ-ACK codebook can be considered to further reduce the overhead. |
| Huawei, HiSilicon | Yes | Sub-slot based type 1 HARQ-ACK codebook is important for URLLC. If it can be addressed in Rel-16, that would be good also. However, the current specification is not sufficient if people think that it is already supported by the Rel-16 specification. For example, determining sub-slot for a PDSCH TDRA as the sub-slot associated with the last OFDM symbol of the PDSCH is not specified yet. |
| LG | No |  |
| InterDigital | Yes | If type 1 CB is supported, payload size optimization would be important. |
| Nokia, NSB | Yes | We think this is essential for Type 1 CB usage for URLLC. So if not supported in REl-16, then should be done in Rel-17. |
| MediaTek | No | Low |

In addition, the following feedback from companies on the priority of issues / enhancements discussed in 1 or 2 contributions input to this meeting has been received (*to be completed by FL after initial round of feedback*):

|  |  |  |
| --- | --- | --- |
| Section | Description | Number of companies indicating High / Medium Low priority |
| X.X | Dummy section name | High: X Medium: Y Low: Z |
|  |  |  |
|  |  |  |

# 3 SPS HARQ-Ack enhancements

In this section, the proposed Rel-17 enhancements of different companies regarding specifically HARQ-ACK operation for SPS are summarized

## 3.1 Avoid SPS PDSCH HARQ-ACK dropping for TDD

In Rel-15 and Rel-16, all the SPS PDSCH of a specific SPS configuration has a fixed PDSCH-to-HARQ timer (K1) as defined in the activation DCI. With the introduction of shorter (down to 1 slot) SPS periodicities in Rel-16, a significant percentage of the SPS HARQ-ACK feedback may be dropped if the corresponding PUCCH resource collides with at least 1 DL or flexible symbol.

Several companies suggest to solve this issue as part of the Rel-17 URLLC HARQ enhancements:

* + HW/HiSi [1], vivo [2], ZTE [3], E/// [4], CATT [7], Intel [9], Len/Moto [10], TCL [11], OPPO [12], Samsung [14], CMCC [15], LGE [17], Nokia/NSB [18], WILUS [25]

The following methods to allow the SPS HARQ-ACK to be transmitted in a later PUCCH are mentioned:

1. Deferring HARQ-ACK until the first available valid PUCCH resource: HW/HiSi [1], vivo [2], E/// [4], CATT [7], Len/Moto [10], TCL [11], CMCC [15], LGE [17]
   * This may be further limited to the maximum configured K1 value from the K1 set: HW/HiSi [1]
   * UE may discard the HARQ-ACK information, If UE cannot transmit HARQ-ACK information within the configured maximum HARQ-ACK feedback delay: Len/Moto [10]
2. gNB dynamic indication of one or more transmission opportunities for the postponed HARQ-ACK to UE: vivo [2]
3. Indicating K1 value for each SPS transmission in a time window configured by RRC: ZTE [3]
4. Support one-shot HARQ-ACK request (i.e. Type 3 CB) for group of SPS HARQ processes: Intel [9]
5. Support non-numerical (i.e. NN k1) for DL SPS operation in licensed spectrum: Intel [9]
6. New HARQ-ACK feedback timing mechanism: TCL [11]
7. HARQ-ACK feedback for all available SPS PDSCHs (incl. payload size optimizations): OPPO [12]
8. UE to select the first applicable k1 value from a set of configured kl1 values to allow HARQ-ACK load balancing: Nokia/NSB [18]
9. Autonomous HARQ-ACK resending or to multiplex the dropped HARQ-ACK information to the different HARQ-ACK information: WILUS [25]

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2.1 due to large company interest. Therefore the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 3.1.1: What is your preferred method (from the above or any additional methods) to solve the issue of SPS HARQ-ACK dropping for TDD?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Sony | Prefer to discuss the solution after we agree on whether to support this feature. |
| Sharp | 1. Deferring HARQ-ACK until the first available valid PUCCH resource |
| DOCOMO | 1 and 4 for further study |
| CMCC | Alt 1 is preferred: Deferring HARQ-ACK until the first available valid PUCCH resource and the definition of “valid PUCCH resource” can be further studied. |
| vivo | We think either implicit or explicit solutions can be considered.  Regarding implicit method, we prefer to deferring HARQ-ACK until the first available valid PUCCH resource since it is the simplest way without any signalling overhead and there is no miss-understanding between gNB and UE on where the dropped HARQ-ACK will be re-transmitted. About the load balancing, we think it can be efficiently handled by gNB by indicating proper K1 based on the TDD configurations and SPS configurations.  Regarding explicit method, the dropped HARQ-ACK can be re-transmitted according to gNB indication, e.g. indicating one or multiple transmission occasions for SPS HARQ-ACK. It provides flexibility for gNB to manage the transmission resources of SPS HARQ-ACK. gNB dynamic indication of one or more transmission opportunities for the postponed HARQ-ACK to UE |
| CATT | 1 |
| Samsung | Defer to first available PUCCH resource as in LTE – no apparent benefit from introducing delay particularly considering that the gNB can distribute the load of periodic/semi-persistent UCI and/or CG PUSCH. |
| ZTE | Alt 3, Indicating K1 value for each SPS transmission by one or more K1 value sets in a time window configured by RRC |
| WILUS | We prefer Alt 1, but it is too premature to down-select single alternative before discussing pros/cons. |
| NEC | We are open to further discuss the above methods. |
| Huawei, HiSilicon | 1  We share similar view as Vivo on the implicit method, it seems sufficient to defer HARQ-ACK until the first available valid PUCCH resource, considering the potential signalling overhead. In addition, since the latency is critical for URLLC, it is preferred that UE will only defer the HARQ-ACK feedback to the first available valid PUCCH resource only if the delay won't exceed the maximum configured K1 value from the K1 set, which can also reuse the current HARQ-ACK codebook generation mechanism as much as possible. |
| LG | 1 |
| InterDigital | Solution 2, 4 and 5 can be considered as one family solution. Since the one-shot HARQ feedback request can be viewed as “more transmission opportunities”. And for the case of NNK1 indication, additional HARQ feedback transmission opportunity can be sent by the gNB later.  We prefer solution 1, 2, 4 and 5. |
| Nokia, NSB | Option 8, as it provides flexible mapping of SPS PDSCH HARQ-ACK to PUCCH resources and thus allows better load balancing of the PUCCH payload.   Some clarifications on some proposals (e.g. 6 from [11], 7 from [12], 9 from [25]) by the proponents would be needed. |

## 3.2 SPS HARQ-ACK payload size reduction / skipping

Several companies raise the issue of high HARQ-ACK payload size and frequent PUCCH transmissions when operating with low SPS periodicities as well as multiple SPS configurations. The motivation by the companies for enhancements here are related to UE power saving, reduction of UL interference, beside others.

The following companies suggest to study / specify techniques to reduce the SPS HARQ-ACK payload size in Rel-17:

* HW/HiSi [1], TCL [11], LGE [17], Nokia/NSB [18]

The following related enhancements are suggested by different companies to be supported in Rel-17:

* ACK skipping (i.e. do not transmit PUCCH, if only SPS ACK to be transmitted): HW/HiSi [1] , TCL [11], LGE [17]
  + LGE [17]: In case that UE fails to decode PDSCH and need to transmit NACK feedback, the UE can request PUCCH resource for the NACK feedback transmission on demand, by certain uplink signaling
* NACK skipping (i.e. do not transmit PUCCH, if only SPS ACK to be transmitted): HW/HiSi [1], TCL [11]
* Only one HARQ-ACK for multiple SPS configurations is feedback, multiple SPS configurations are configured to support one service with jitter: OPPO [12]
* gNB can disable HARQ-ACK feedback for one or multiple SPS configurations: Nokia/NSB [18], [OPPO [12]??]

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2.1 due to large company interest. Therefore, the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 3.2.1: What is your preferred method (from the above or any additional methods) to reduce the SPS HARQ-ACK payload size?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Sony | Do not think this is required. |
| DOCOMO | ACK or NACK skipping for further study |
| CMCC | Medium priority |
| vivo | Low priority |
| CATT | TBD. The benefits should be justified first. |
| Samsung | No need. This also seems related to a previous question. Note that fall-back for single SPS PDSCH reception is already supported.  If coding is with an RM code (likely), benefit is small or none.  If coding is with a polar code, overhead reduction would be small/marginal. |
| ZTE | Low priority |
| WILUS | Medium. High spec impact at least on HARQ-ACK codebook designs is expected if ACK skipping or NACK skipping is supported. |
| Huawei, HiSilicon | 1. We think ACK skipping should be supported, which can get some benefits like reducing interference or saving UE power consumption. Skip PUCCH transmission if only ACK are to be transmitted, to avoid the ambiguity issue.   Disabling HARQ-ACK feedback can be considered also. In some use case, disabling HARQ-ACK feedback would not bring any harm, e.g. for motion control system, closed loop operation is usually performed among controller, actuator and sensor. That is, when there is DL transmission between controller and actuator, usually there is corresponding UL transmission between sensor and controller. In this case, gNB can rely on whether there is corresponding UL transmission for a DL transmission to identify whether it is ACK or NACK. |
| LG | ACK skipping has beneficial point in terms of URLLC. |
| InterDigital | We think payload size reduction is needed for SPS HARQ-ACK to reduce the HARQ-ACK overhead in case of multiple SPS configuration having short periodicity. We think that all of the above methods should be considered. |
| Nokia, NSB | We support that gNB can disable HARQ-ACK feedback for one or multiple SPS configurations.  While we understand the reasoning for ACK- or NACK-skipping, we do not prefer this direction because:   * + - PUCCH resources for the potential HARQ-ACK feedback needs to be reserved and received by the gNB anyway.     - When operating with multiple SPS configurations or when the SPS HARQ-ACK is multiplexed with dynamic traffic HARQ-ACK, the SPS HARQ-ACK need to be anyway transmitted (regardless of whether is a ‘ACK’ or ‘NACK’ to ensure aligned HARQ-ACK codebook size between gNB and UE.     - Large standardization effort is expected if this would not just apply to PUCCH carrying SPS HARQ-ACK only. |

## 3.3 SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCH

According to current NR specification, UE shall report HARQ-ACK feedback for each configured SPS PDSCH occasion, even though there is no actual downlink transmission for a SPS PDSCH occasion. However, the traffic of some URLLC use cases is non-periodic. In such case, the SPS configuration with shorter periodicities would be configured to meet the low latency requirement. However, some redundant HARQ-ACKs will be generated for the SPS occasions with no actual transmission. Several companies raise the issue that HARQ-ACK transmission could be skipped if SPS PDSCH is not transmitted by the gNB (i.e. ‘skipped’).

The following companies support SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCH:

* vivo [2], ZTE [3], E/// [4], CMCC [15], QC [24]

The following methods for the UE to identify a ‘skipped SPS PDSCH’ are discussed:

* Alt. 1: Based on DM-RS presence detection: vivo [2]
* Alt. 2: Skip PUCCH transmission if only SPS NACK is mapped: E/// [4]
* Alt. 3. Through dynamic signaling (‘Skipped SPS PDSCH DCI’): QC [24]

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2.1 due to large company interest. Therefore, the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 3.3.1: What is your preferred method (from the above or any additional methods) to reduce the SPS HARQ-ACK payload size especially considering ‘skipped’ SPS PDSCH transmissions?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Sony | Discuss solution after we agree to support this. |
| Sharp | We support Alt. 1. |
| DOCOMO | Alt.2 |
| CMCC | We are open to the solutions mentioned above. |
| vivo | Alt.1. Based on DMRS detection, UE can know whether the DL SPS PDSCH is present or not. In Rel.16, it is observed by DMRS detection, the probability of miss-detection of the transmission for URLLC is low. |
| CATT | TBD. The benefits should be justified first. |
| Samsung | No need.  If coding is with an RM code (likely), benefit is small or none.  If coding is with a polar code, overhead reduction would be small/marginal.  For only one SPS PDSCH reception, can consider fall-back codebook based on the same principle as for fall-back in Rel-15. |
| ZTE | High priority. Our preference is to identify a ‘skipped SPS PDSCH’ is via the DAI piggyback in the PDSCH. |
| WILUS | Medium. Among three options, Alt 1 or 2 for further study. |
| Huawei, HiSilicon | Alt.2 looks better considering the potential ambiguity issue if skipping is transmitted with other HARQ-ACK feedback. However, we are open to discuss other solutions also. |
| LG | TBD. The benefit of SPS skipping is marginal since it may not reduce payload size when dynamic PDSCH is scheduled. |
| InterDigital | As a first step we should agree to whether support or not the reduction mechanisms for SPS HARQ-ACK payload. |
| Nokia, NSB | Alt. 2 from E// seems the most simple/straightforward so it may be worth to further study. |

## 3.4 Explicit HARQ-ACK for SPS activation / reactivation DCI

As discussed in [24], currently (re)Activation DCI is transmitted so as to define / modify some of the PHY parameters of an SPS PDSCH configuration. With this SPS (re)Activation DCI, the network can request specific PUCCH format for the first PDSCH following the SPS (re)Activation DCI. This new format is valid only for one occasion and the network has the option to use either the same PUCCH A/N format used for SPS or a different PUCCH A/N format. In case, the network chooses to use the same PUCCH A/N format for PDSCH following the SPS (re)Activation DCI, then, there might be an ambiguity upon SPS (re)Activation DCI reconfiguring the DL beam.

To avoid such ambiguity, explicit HARQ-ACK feedback for SPS activation / reactivation DCI for Type 1 HARQ-ACK CB could be supported, as suggested by the following companies:

* QC [24]

**FL request 3.4: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium:**
* **Low: DOCOMO CMCC, vivo, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| vivo | Low.  Firstly, we are not clear about the mentioned ambiguity. For URLLC case, we think the probability of miss-detection the reactivate DCI should be very low.  Secondly, even if there may exist ambiguity, it will be recovered by gNB’s judgement when it continuously receives the DTX/NACK. |
| Samsung | Low.  Overall problem is rather marginal and can be addressed by gNB implementation and/or configuration of PUCCH resource sets. |
| InterDigital | Low. Based on our understanding of this issue, the problem happens when the gNB reactivate/change the transmission parameters of the SPS PDSCH and the UE is still able to correctly decode the DL SPS transmission (with previous DL SPS transmission parameters) and sends ACK. |
|  |  |

## 3.5 Selection of SPS PUCCH A/N resource through (re-)activation DCI

As discussed in [24], Release 16 allows modifications of SPS parameters via SPS (re)Activation DCI. SPS PUCCH A/N can be configured at RRC level. However, in some cases an issue might be detected in the current SPS PUCCH A/N configuration and the response time, i.e. the modification of the current SPS PUCCH A/N via RRC signaling, will be several msec. This delay is not acceptable in the case of IIOT, where the latency requirement sometimes can be 1 or 0.5 msec.

To reduce the latency in applying a different SPS PUCCH A/N resource, the SPS activation DCI can update (or define) the SPS PUCCH A/N resource, as suggested by the following companies:

* QC [24]

**FL request 3.5: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: HW/HiSi, LG**
* **Low: DOCOMO CMCC, vivo, CATT, Samsung, ZTE, Panasonic, NEC. LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| vivo | Low.  Using RRC to reconfigure the PUCCH resource is more reliable compared to using DCI. In addition, for URLLC services, any RRC reconfiguration may cause some delay in applying the updated configurations. Not sure why this is problem especially for SPS PUCCH resource, re-configure PUCCH resource for dynamic PDSCH also face the similar “issue”? |
| Samsung | Low.  Overall problem is rather marginal and can be addressed by gNB implementation. |
| InterDigital | Medium. This can be discussed after we make progress on the higher priority issues. |
|  |  |
|  |  |

## 3.6 HARQ process collision for low SPS periodicities

In [26], the issue of having still pending re-transmissions for a SPS HARQ process and due to the low periodicity (and limited number of HARQ processes configured for the SPS configuration) may lead to soft-buffer flushing before successful reception of the TB. Therefore, transmitting HARQ-ACK information of an already flushed HARQ process is not really helping the HARQ-ACK operation.

Therefore, it is suggested by the following companies to study HARQ enhancement regarding to multiple active SPS configurations and short SPS periodicity:

* Google [26]

**FL request 3.6: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: LG**
* **Low: DOCOMO CMCC, vivo, CATT, Samsung, ZTE, Panasonic, NEC, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| vivo | Low.  It can be avoided by gNB scheduling/configuration (not perform dynamic PDSCH scheduling to override the SPS PDSCH using the same HARQ process or configure larger number of HARQ process(es)) |
| Samsung | Low  Even for 16 SPS PDSCH configurations and for a shortest periodicity of 1 msec (for some of them), there does not seem to be a problem with running out of HARQ processes before providing HARQ-ACK feedback. Soft buffer flushing is always a possibility but it is more likely for eMBB than for URLLC due to the small TBS and the very low BLER where even a small buffer suffices. |
| LG | It may be necessary to discuss for facilitating 1 slot periodicity SPS. As Configured grant, it can be considered for UE to skip SPS PDSCH occasion under some condition (i.e., timer) |
| InterDigital | This issue can be avoided by configuring a value of K1 that is short enough with respect to the periodicity of the SPS PDSCH. |

# 4 Sub-slot PUCCH /HARQ-ACK related enhancements

In this section, the proposed Rel-17 enhancements of different companies regarding enhancements with respect to Rel-16 sub-slot PUCCH are summarized. Please note, that sub-slot PUCCH repetition is discussed as part of HARQ-ACK reliability enhancements in Sec. 4.

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

Currently, in the Rel-16 maintenance there is still some discussion if Type 1 HARQ-ACK codebook with sub-slot PUCCH configuration is supported or not.

Independently, the following companies suggested in their contributions to support Type 1 HARQ-ACK codebook for subslot PUCCH as part of the Rel-17 enhancements (or at least support some enhancements in Rel-17, if not supported in Rel-16):

* HW/HiSi [1], ZTE [3], CATT [7], NEC [8], OPPO [12], Spread [16]

The following procedures on how to define the sub-slot Type 1 HARQ-ACK are mentioned by different companies:

* HW/HiSi [1]: “*For example, the associated sub-slots of a given UL sub-slot can be determined based on the configured K1 set, then for each sub-slot the SLIVs whose ending symbols are located in this sub-slot are selected from the configured SLIV set and the SLIV splitting is performed for these SLIVs belonging to the same sub-slot to get the PDSCH occasion per sub-slot*”
* CATT [7]: *Remove redundant HARQ-ACK bits based on the boundary of UL sub-slots*
* NEC [8]:
  + *Step 1: Determine the HARQ-ACK multiplexing window based on the HARQ-ACK timing set and sub-slot length.*
  + *Step 2: Split the TDRA table into N sub-tables based on the sub-slot length and PDSCH-to UL sub-slot association. N is the number of sub-slot within a slot.*
  + *Step 3: Do pruning based on TDD configuration and sub-table per sub-slot similar as Rel-15.*
* OPPO [2]: *For a given sub-slot, if the last symbols of the PDSCH time resource derived by a TDRA row r is not in the sub-slot, row r is removed from the cardinality of TDRA rows.*
* Spread [16]: *Similar as Rel-16 type 1 codebook, the union set of row indexed of TDRAs are used to determine the PDSCH occasions, including for DCI formats the UE is configured to monitor PDCCH and reference of SLIV if it is configured.*

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2.1 due to large company interest. Therefore, the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 4.1.1: How to support the Type 1 HARQ-ACK codebook based on sub-slot PUCCH by the end of Rel-17? Please indicate your preferred method from the methods provided above or any additional input.**

|  |  |
| --- | --- |
| *Company* | *View* |
| DOCOMO | Can be discussed based on the outcome of Rel.16 maintenance |
| CMCC | we are open to the above optimization for HARQ-ACK payload, i.e. SLIV splitting based on the boundary of UL sub-slots, different HARQ-ACK codebooks and so on. |
| CATT | Can be discussed based on the outcome of Rel.16 maintenance |
| Samsung | Medium.  Simple extension on top of Rel-15/16 type-1 codebook is expected. The enhancement to reduce HARQ-ACK codebook size can be considered. |
| ZTE | High priority. Maximum reuse the principle for slot-base codebook. Identify the specific issue for sub slot, for example, PDSCH cross the sub slot boundary. |
| NEC | We prefer a simple solution to split the TDRA table into N sub-tables for the corresponding N sub-slots in a slot based on the ending symbol of the SLIV. |
| Huawei, HiSilicon | Actually it seems the details from different companies the essential idea is similar, i.e. can do some simple extension based on slot-based type 1 HARQ-CK codebook. The structure given by NEC is clear, with the clarification that determining the sub-slot according to the last symbol of the SLIV in step 2. |
| LG | Can be discussed based on the outcome of Rel.16 maintenance |
| Nokia. NSB | We prefer the method described in [8] by NEC.  For mixed numerology, an additional step is needed to support the case where a sub-slot starts in DL slot #i and ends in DL slot #i+1. To cover this a union of TDRA tables is needed first (with S adjustments). |

## 4.2 Issue of limited k1 range for sub-slot PUCCH for TDD

In Rel-15/16 for a DG PDSCH reception ending in slot n, the UE transmits the HARQ-ACK PUCCH in slot n+k where k is RRC configured or indicated by DCI. In Rel-16, if UL sub-slot is configured, the unit of k is changed from slot to sub-slot.

It is discussed in [3] (and previously discussed in Rel-16 already), that the value range for k1 being limited to 15 may limit the TDD operation for DL heavy TDD configurations and 2-symbols sub-slots, i.e. it will not be possible to indicate a valid PUCCH with k1<=15.

The following companies suggest to address this identified issue in Rel-17:

* ZTE [3]

The following solutions to overcome this limitation have been presented:

* Increased value range for k1 (i.e. k1>15) for sub-slot PUCCH operation: ZTE [3]
* k1=0 to be defined as the first valid PUCCH sub-slot. ZTE [3]

**FL request 4.2: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: CMCC, ZTE**
* **Medium: Samsung**
* **Low: DOCOMO, vivo, CATT, Panasonic, NEC, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. This has been discussed a few times in Rel-16 without any agreement. |
| Sharp | Low priority. |
| CMCC | We are open to be solutions mentioned above with slight preference to increase value range of K1. |
| vivo | Low.  There were discussions for this issue in Rel.16. For URLLC requiring the low latency, it is still questionable whether such DL heavy UL-DL configurations plus configuring 2-symbol sub-slot PUCCH is typical or not. |
| CATT | Low. No need to repeat the discussion. |
| Samsung | Medium  This is a recurring general issue and a similar one is considered in MIMO. |
| ZTE | High priority. The shrink of k1 indication for sub slot is a valid issue which ever raised by CMCC. We are open to the solutions. Just mention that, the solution k1=0 is very similar to the ‘defer’ solution in issue 3.1 which the only difference is issue 4.2 is for DG transmission but issue 3.1 is only for SPS transmission. |
| Huawei, HiSilicon | This was discussed in Rel-16 but not agreed. However, we think there is some use case to enlarge the range. |
| Nokia, NSB | Low priority. If k1 values larger than 15 sub-slots is needed, then the benefits of using sub-slots is getting negligible. We do see that k1=0 could be considered if the above mentioned scenario is used. |

## 4.3 Enhanced (sub-slot) HARQ-ACK multiplexing on PUSCH

In [10] & [25], limitations in terms of HARQ-ACK multiplexing when operating with sub-slot PUCCH are identified.

In [10] it is mentioned that in Rel-16 NR, a UE can be configured with a sub-slot based HARQ-ACK feedback procedure in order to support low latency HARQ-ACK feedback. However, the Rel-16 NR allow the UE to perform multiplexing of uplink control information (UCI) including HARQ-ACK information into a PUSCH based on a slot-based HARQ-ACK feedback framework. For example, according to TS 38.213 [2], “a UE does not expect to multiplex in a PUSCH transmission or in a PUCCH transmission HARQ-ACK information that the UE would transmit in different PUCCHs.” Thus, if a PUSCH or PUCCH with longer duration in a slot is scheduled together with multiple short PUCCHs carrying sub-slot based HARQ-ACK information in the slot, the UE may drop most of the sub-slot based HARQ-ACK information and accordingly, the low-latency HARQ-ACK feedback may not be fully realized.

[25] discusses that in Rel-16, if a UE is scheduled with two PUCCHs in a slot, then gNB cannot schedule a PUSCH overlapping the two PUCCHs in the slot. In other words, the PUSCH should be scheduled to symbols not overlapping the PUCCHs in the slot, which results in lower reliability or higher latency. Moreover, if PDCCH scheduling PDSCH reception is later than the PDCCH scheduling PUSCH, then the HARQ-ACK information for the PDSCH reception is omitted in the type-1 HARQ-ACK codebook, which is another severe limitation.

To fully exploit the benefit of sub-slot based HARQ-ACK feedback without stringent PUSCH/PUCCH scheduling restrictions, RAN1 may have to consider enhancing UCI multiplexing rules (including timeline requirements mentioned in [10]).

Therefore, the following companies propose to enhance UCI multiplexing rules (including timeline requirements) for effectively multiplexing sub-slot based HARQ-ACK feedback information on PUSCH:

* Len/Moto [10], WILUS [25]

**FL request 4.3: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: DOCOMO CMCC vivo, Panasonic, NEC, Nokia/NSB**
* **Low: vivo, CATT, Samsung, ZTE, LG, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium |
| Sharp | High priority. Should this one be handled in 8.3.3 instead? |
| vivo | Low or Medium. From our understanding, the enhancements are related to HARQ-ACK multiplexing on PUSCH with same and/or different priorities. It is better to be discussed in intra-UE multiplexing. |
| Samsung | Low.  Likelihood of the overall scenario is unclear. Should first consider more general solutions that eliminate all such issues such as simultaneous PUSCH and PUCCH transmissions. |
| ZTE | This could be considered in agenda 8.3.3 |
| WILUS | High priority. It can be handled in 8.3.1.1 or 8.3.3. |
| NEC | Medium.  We think this issue can be discussed in AI 8.3.3. |
| LG | Low. If it is a real issue, it should be handled in 8.3.3 to avoid misalignment |

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

In R16, the sub-slot configuration is RRC configured which does not allow for a more frequent change of the applicable sub-slot configuration of a PUCCH config (i.e. only slow adaptation possible). In contrast, it is discussed in [24] that the gNB could configure multiple sub-slot configurations to the UE by RRC, which can then be (more) dynamically selected based on MAC CE signaling.

The following companies suggest supporting to use MAC-CE to switch between multiple sub-slot configurations for HARQ-ACK feedback:

* QC [24]

**FL request 4.4: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium:**
* **Low: DOCOMO CMCC, vivo, CATT, Samsung, ZTE, Panasonic, NEC, HW/HiSi, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. |
| vivo | Low. In Rel.16, only 2-symbol and 7-symbol sub-slot is supported. We do not see the use case or motivation for dynamic changing of the sub-slot configurations. Rather we see much complexity and ambiguity between gNB and UE for dynamicly switching the sub-slot configurations. |
| Samsung | Low – motivation is ad-hoc. |
| HW/HiSi | Dynamic change of the sub-slot configuration would make it more complex for HARQ-ACK feedback, especially type 1 HARQ-ACK codebook. |
| InterDigital | Low |

# 5 HARQ-Ack reliability enhancements

In this section, the proposed Rel-17 enhancements of different companies regarding enhancements improving the HARQ-Ack reliability are summarized.

## 5.1 ‘Sub-slot’ type of PUCCH repetition

Sub-slot type of PUCCH repetition can improve the reliability (through repetition). Currently, in the Rel-16 maintenance there is still some discussion if sub-slot PUCCH repetition is supported or not.

The following companies state that sub-slot based PUCCH repetition is supported in Rel-16:

* E/// [4], Pana [19]

Other companies suggest in their contributions to support ‘sub-slot’ type of PUCCH repetition as part of the Rel-17 URLLC HARQ-ACK feedback enhancements:

* HW/HiSi [1], Intel [9], Samsung [14], DCM [23]

The following related techniques and related needed enhancements are discussed by different companies:

* PUCCH repetition using PUSCH repetition Type B principles: HW/HiSi [1], Intel [9], Samsung [14]
  + Such enhancement is not needed: E/// [4]
* PUCCH repetition from sub-slot to sub-slot (using slot based repetition principles): HW/HiSi [1], E/// [4], Samsung [14], DCM [23]
* Dynamic indication of PUCCH repetition (in DCI): E/// [4], Pana [19]
* Support of PUCCH repetition of short PUCCH formats (i.e. formats 0 & 2): E/// [4], Samsung [14], Pana [19], DCM [23]
  + Prioritize relatively ‘short’ long PUCCH: Intel [9]
* Support PUCCH repetition based on UCI type (e.g. no rep. if only CSI but no HARQ): E/// [4]

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2 due to large initial company interest. Therefore the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 5.1.1: Which enhancements / solutions in the area of ‘sub-slot’ Type of PUCCH repetition are to be supported by the end of Rel-17 (if not supported in Rel-16 already)?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Sony | There are some issues with collision with other (adjacent) sub-slot’s PUCCH. We can discuss the solution after agreeing to support this feature. |
| Sharp | For short PUCCH, repetitions within and across sub-slots can be supported.  For sub-lot based long PUCCH, sub-slot to sub-slot is sufficient. |
| DOCOMO | Sub-slot based PUCCH repetition with short PUCCH formats |
| vivo | Low priority |
| CATT | Low priority. Evaluation results are needed to justify the benefit first. |
| Samsung | For FR2, support PF0/2 repetitions - this may or may not be addressed in the coverage enhancements WI or the MIMO WI.  In general, have the number of repetitions be at least dynamically indicated. This may also be addressed in the coverage enhancement WI. |
| ZTE | We suggest jointly considering this issue with WID of coverage enhancement. |
| Panasonic | Sub-slot based PUCCH repetition with short PUCCH formats and dynamic indication of the number of PUCCH repetitions. |
| WILUS | Low priority for sub-slot PUCCH repetition with long PUCCH format. We are fine to discuss sub-slot PUCCH repetition with short PUCCH format |
| Huawei, HiSilicon | PUCCH repetition over sub-slot should be supported at least for short PUCCH format for achieving reliability and low latency. It would be good to introduce some mechanism to ensure flexible number of repetitions. |
| LG | Low. |
| Nokia, NSB | No need to support additional enhancements for sub-slot type of PUCCH repetitions on top of Rel-16 (which supports 7OS sub-slots).  No need for repetition Type B principles applied to PUCCH. |

## 5.2 PUCCH TPC enhancements for HP HARQ-ACK

The arguments for supporting TPC enhancements for PUCCH are given by the needed different reliability of HARQ-ACK for high-priority and low priority traffic, which with the currently available limited value range of TPC cannot be covered. On further details, the interested reader is referred to the discussions in [1].

Enhancements to PUCCH TPC are suggested by the following companies:

* HW/HiSi [1]

The following related enhancements are mentioned in companies’ contributions:

* Increased TPC range for PUCCH: HW/HiSi [1]
* Dynamically indicating open-loop power control of PUCCH in DCI: HW/HiSi [1]

**FL request 5.2: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: CMCC, HW/HiSi, MediaTek**
* **Low: DOCOMO, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. |
| Sharp | Low priority.  Different power control parameters are already supported with different PUCCH-Configs. Further enhancement should be given with low priority. |
| vivo | For indicating the open-loop power control of PUCCH by DCI, it seems already can be achieved in Rel.16. |
| Samsung | Low.  If anything is needed, re-use Rel-16 mechanism for indicating different Po values instead of adding a separate TPC look for URLLC than for eMBB. |
| LG | Low, we already have separated power control parameter for different PUCCH configuration. |
| InterDigital | Low. The priority index already allows selection of different open-loop parameters for PUCCH. |

## 5.3 Large-delay CDD support for PUCCH

Spatial diversity PUCCH transmission, such as using non-transparent (i.e. large-delay) CDD, can improve the PUCCH reliability as shown by extensive evaluations in [6]. This can improve the missed-ACK detection probability and thereby reduces the resource utilization due to unnecessary PDSCH retransmissions.

The following companies propose to support non-transparent (i.e. large-delay) CDD for PUCCH transmission for Rel-17 URLLC to enhance the PUCCH reliability:

* MTK [6]

**FL request 5.3: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: MediaTek**
* **Medium:**
* **Low: DOCOMO CMCC vivo, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low |
| vivo | Low. In Rel.15, the non-transparent (i.e. large-delay) CDD was discussed, and none of channels support the TxD. |
| Samsung | Low.  TxD may be introduced in other WIs (e.g. coverage enhancements) due to stronger motivations and the scheme may then be considered for URLLC. However, an diversity order of 8 provides all gains and can be achieved with 4 Rx antennas and 1 FH (also, in TDD, base stations typically have more than 4 Rx antennas). |
|  |  |

## 5.4 Enhanced DAI definition for URLLC

In [8] it is discussed, that when considering the higher possibility of blockage for FR2 higher frequencies, a burst of four or more missed detection may occur across the slots/sub-slots due to mobility or fast fading. The transient changes in channel condition may not be mitigated by lowering the code rate. The DAI counters for the dynamic codebook can be redefined to ensure reliability for URLLC. The new definition helps to locate the errors to within a slot. The total-DAI field can be redefined for the non-carrier aggregation case in Rel-17 DCI for URLLC.

To enhance the reliability of dynamic codebook, *the existing T-DAI field, which is not currently present for URLLC cases, may be simply redefined*:

* New Definition of T-DAI: The value of the T-DAI, when configured as ‘present’, in DCI format 1\_1 (or DCI format 1\_2) denotes the total number of slots in which PDSCH transmission(s) associated with DCI format 1\_1 (or DCI format 1\_2) occur(s), up to the current slot, in increasing order of slot index.

The following companies suggest to enhance the DAI definition for Type 2 HARQ-ACK operation in Rel-17:

* NEC [8]

**FL request 5.4: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: NEC**
* **Medium:**
* **Low: DOCOMO, CATT, Samsung, ZTE, Panasonic, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. Increasing the C-DAI value can be an easier straightforward solution. |
| vivo | Low. The FR2 blockage issue requires more general enhancements. Not special for URLLC. In addition, the new definition of total DAI is from PDSCH reception perspective (may or may not include the SPS PDSCH without associated DCI) and the counter DAI is from PDCCH monitoring perspective, it cannot be extended to CA case. |
| Samsung | Low.  If beam blockage happens, there are bigger issues than expanding the range of the DAI counters (including not being able to provide accurate PUCCH in the typical case of beam correspondence). Rel-17 MIMO includes aspects for improving robustness in FR2. |
| InterDigital | Low |

## 5.5 Support of lower effective code rate for HARQ-ACK

The currently supported minimum code rate of PUCCH of 0.08 is much higher compared to UL-SCH & DL-SCH data of 0.029. Therefore, to improve the reliability the minimum coding rate for HARQ-ACK could be reduced as discussed in detail in [15].

The following companies suggest supporting lower code rate values for *maxCodeRate* for HARQ-ACK on PUCCH in Rel-17:

* CMCC [15]

The following options to enable a lower code rate for HARQ-ACK on PUCCH have been discussed:

* Add some low-code rate entities to the table of maxCodeRate: CMCC [15]
* Define two tables of PUCCH maxCodeRate for different PHY priority. The PUCCH maxCodeRate table for PHY priority 1 can be generated by adding some entries with lower code rate and removing entries with higher code rate: CMCC [15]
* a beta offset can be added to maxCodeRate when determining the minimum number of PRBs for PUCCH resource for PUCCH format 2 or PUCCH format 3, or some adjustment is applied to the determined minimum number of PRBs: CMCC [15]

**FL request 5.5: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: CMCC, ZTE**
* **Medium: LG**
* **Low: DOCOMO vivo, CATT, Samsung, Panasonic, NEC, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium |
| Sharp | Low priority.  The low code rate can also be achieved by PUCCH repetition, which should be given with higher priority. |
| CMCC | Low code rate for PUCCH can achieve lower latency comparing to sub-slot/mini-slot PUCCH repetition. Moreover, it is observed that PUCCH is power unlimited in most cases, so support of lower effective code rate for PUCCH is an effective way to enhance PUCCH reliability within a certain delay budget. |
| vivo | Low. The solution can only be used when UE is not power limited. While if UE is not power limited, boost the Tx power can achieve the same purpose and much simpler compared to lowering the code rate. |
| Samsung | Low.  The minimum code rate is already so low that there is no coding gain for polar codes from reducing further. Any problem can be addressed by power boosting or, if power limitation, by a longer PUCCH resource. |
| ZTE | This issue has been raised in 8.3.3 by several companies, we can switch it to agenda 8.3.3 |
| LG | Could be medium. However, maxcoderate would change the number of RB for the PUCCH so it would not be helpful due to UE power limitation. |
| MediaTek | Low |

## 5.6 Different PUCCH resources for ACK and NACK

As discussed in [24], there could be a different payload size for ‘NACK’ compared to ‘ACK’, especially fi additional information is transmitted together with a NACK (as proposed by different companies here, e.g. Tri-state HARQ-ACK of Sec. 6.16).

In the special case, in which the error occurred due to beam blocking, very likely the uplink will be blocked as well. The UE can transmit NACK via several beams, which might not be the case for ACK transmission.

As another example, in case PDSCH decoding failed due to frequency selective fading, the UE might want to repeat PUCCH in subbands which do not experience frequency selective fading. Hence, PUCCH resources to be used for NACK are different for the PUCCH resources to be used for ACK.

Therefore, the following companies suggest supporting ACK and NACK transmission on different PUCCH resources:

* QC [24]

**FL request 5.6: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: DOCOMO**
* **Low: vivo, CATT, Samsung, ZTE, Panasonic, NEC, HW/HiSi, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | High. If we want to provide more info such as CSI or others to the gNB in a NACK, it make sense to use a different resource in time/frequency for NAK |
| vivo | Low. Different PUCCH resources for ACK/NACK cause additional overhead and blind detection at gNB side. When considering the UCI multiplexing with the PUSCH, it causes more complexity. |
| Samsung | Low.  For 1-2 bits of HARQ-ACK, this will result to worse HARQ-ACK BLER as DTX needs to be separately determined. NACK BLER would also increase as the amount of information increases and, without CRC protection, BLER in the order of 10^-6 cannot be assumed achievable especially when, in TDD, link adaptation is likely poor (hence the NACK). Also, given the very low probability of a NACK and the possible interference bursts as a cause, short term information is of little/no value. |
| Huawei, HiSilicon | It seems the motivation to do this is in order to provide feedback on other information, however it seems those feedback doesn't belong to HARQ-ACK feedback enhancements scope? |
| LG | Low. The benefit should be justified considering expected effort and complexity/overhead on codebook construction. |
| InterDigital | Medium. We should first discuss the support of a UE sending additional information along with a NACK feedback, then we can discuss the resource carrying such additional information. |
| MediaTek | Low |

# 6 Other HARQ-ACK related enhancements

In this section, the proposed Rel-17 HARQ-ACK enhancements of different companies not directly related to the previous sections.

## 6.1 Retransmission of Canceled / Dropped Low-priority HARQ-ACK

Based on Rel-16 intra-UE and inter-UE prioritization, low priority HARQ-ACK transmission may be dropped /canceled due to overlapping HP UL channels (for intra-UE prioritization) or due to UL cancelation indication using DCI format 2\_4 (for HARQ-ACK carried on PUSCH). This leads to LP HARQ-ACK dropping affecting the eMBB PDSCH performance (from single UE but especially from cell load perspective) which could be improved by allowing a later re-transmission of canceled / dropped LP HARQ-ACK.

The following companies propose to support this short-coming of dropped / canceled HARQ-ACK transmission due to intra-UE or inter-UE prioritization (by allowing a type of ‘re-transmission’ of HARQ-ACK):

* ZTE [3], OPPO [12], Samsung [14], Pana [19], APT [22], DCM [23], WILUS [25], E/// in R1-2005516, MTK in R1-2005636

The following solutions to solve this short coming are discussed by different companies:

* Alt. 1: gNB indicating a new PUCCH resource for ‘re-transmission’: ZTE [3]
* Alt. 2: Enhanced Type 2 CB from NR-U (i.e. PDSCH grouping): Pana [19], APT [22], E/// in R1-2005516
* Alt. 3: Type 3 CB from NR-U: Pana [19], APT [22], DCM [23], WILUS [25], E/// in R1-2005516
* Alt. 4: NNK1 feature from NR-U: E/// in R1-2005516
* Alt. 5: querying the UE’s history of deprioritized Low priority HARQ codebooks and trigger the HARQ-ACK transmission similar as for A-CSI: MTK in R1-2005636

*Feature lead: The discussion on priority for this topic due to large number of initial support is already handled in Sec. 2.1 due to large company interest. Therefore, the discussions in this section below should focus on technical solutions to solve the issue provided above or any additional input from you side.*

**Question 6.1: What is your preferred method (from the above or any additional methods) to enable retransmission of canceled / dropped Low-priority HARQ-ACK ?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Sony | This can be considered in AI 8.3. |
| DOCOMO | Alt.3 |
| CMCC | For low-priority HARQ-ACK drop due to intra-UE prioritization, it is preferred to discuss in AI 8.3.3 to multiplex LP HARQ-ACK on HP PUCCH/PUSCH.  For low-priority HARQ-ACK drop due to inter-UE cancelation, we are open to the above solutions. |
| vivo | We are open for all three alternatives with slightly preference of Alt.2 and Alt.3, NR-U based schemes can be the baseline. |
| CATT | TBD. |
| Samsung | Focus/preference should be on methods that re-use available means on non-shared spectrum.  NR-U schemes may exist on paper but they don’t exist in licensed spectrum implementations and should not be assumed as available. Although it can be OK to support retransmission of dropped HARQ-ACK using NR-U schemes, that cannot be the primary/only approach.  TBD is this should be discussed in this AI or AI 8.3. |
| ZTE | Alt 1 |
| Panasonic | Alt.2 or Alt.3. We agree with Sony that this topic can be considered in AI 8.3.3. |
| NEC | Alt.1 or Alt.3 is slightly preferred. |
| LG | The necessity of this issue is up to AI 8.3. Moreover, this issue can be alleviated by section 3 in this document. It should be avoided duplicated discussions and designs. |
| InterDigital | Alt1, Alt2, Alt3 and Alt4. |
| Nokia, NSB | First we would need to discuss for what use cases this is done. Discuss the solutions later on. |
| MediaTek | We proposed Alt. 5, but we are fine with reusing existing NR-U solutions. |

## 6.2 Dynamic PUCCH carrier switching (for TDD carriers)

The latency of PUCCH may be impacted by the TDD configurations. Allowing dynamically (in the scheduling DCI) to indicate carrier (for a CA setup) where PUCCH is to be transmitted can reduce the HARQ-ACK latency. Further details can be found in [1] and [6].

The following companies propose to support dynamic indication of the carrier carrying PUCCH within a cell group:

* HW/HiSi [1], MTK [6]

**FL request 6.2: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: HW/HiSi, MediaTek**
* **Medium: DOCOMO CMCC, Samsung, NEC, Nokia/NSB**
* **Low: vivo, CATT, ZTE, Panasonic**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. |
| vivo | Low. To support URLLC, proper UL-DL configuration should be configured by gNB. The benefit is not clear while the specification impact is big. |
| Samsung | Medium. Would require additional power control loop(s) for the PUCCH and additional UE capability (like support of multiple PSCells). |
| Huawei/HiSilicon | TDD is also a very important scenario for NR, however it can be expected that the latency is not that good based on the current mechanism. We cannot always rely on adjusting the configuration to match the latency requirement, because it cannot meet the latency requirement for both UL and DL. |
| Nokia, NSB | Medium This could improve latency – with limited specs impact (just a matter of more PUCCH configs on SCell and dynamic DCI signaling) |
| MediaTek | High.  TDD is essential for URLLC due to the wide BW availability. However, TDD pattern is a bottleneck for the latency in real deployments. Dynamic PUCCH carrier switching can address the issue efficiently. |

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

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

It is proposed, that in Rel-17 for HP HARQ-ACK CB only a single HARQ-ACK bit would be generated.

This enhancement is supported by the following companies:

* HW/HiSi [1]

**FL request 6.3: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: HW/HiSi**
* **Medium: vivo, NEC**
* **Low: DOCOMO, CATT, Samsung, ZTE, Panasonic, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. |
| vivo | Medium. Seems simple way to reduce the HARQ-ACK codebook size for URLLC. We are open to study. |
| Samsung | Low.  There are much bigger problems that prevent use of a same DCI format to schedule both eMBB and URLLC. |
| NEC | Medium.  The optimization of Type-1 HARQ-ACK codebook for URLLC seems reasonable. |
| Huawei/HiSilicon | It is a very simple enhancements while can bring reliability gain for URLLC. |
| InterDigital | Medium |

## 6.4 ‘Fast NACK’ to reduce re-transmission delays

In [5], it is proposed to support ‘fast NACK’ reporting, to enable quick re-transmission of incorrectly decoded PDSCH.

The following behavior is described in [5]:

* NACK for a PDSCH can be transmitted earlier than the scheduled PUCCH, whereas an ACK for a PDSCH is transmitted at the scheduled PUCCH.
* UE sends a Fast NACK if it fails to decode a PDSCH and the PDSCH-PUCCH delay k1 > TDelay.
* Fast NACK can be carried by PUCCH Format 0 or Format 1, to allow multi-user multiplexing

‘Fast NACK’ enhancements are supported by the following companies:

* Sony [5]

**FL request 6.4: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: DOCOMO, Panasonic**
* **Low: vivo, CATT, Samsung, ZTE, NEC, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | High. Supporting a single shot PDSCH meeting 10-5/10-6 BLER would require lots of resource. Typically, it is more efficient to use retransmission where each transmission can target a higher BLER. Hence to also meet the latency requirement, retransmission needs to occur as soon as possible and therefore it make sense to provide a NACK as soon as the UE fails to decode the PDSCH. |
| vivo | Low. This is similar as the enhancement listed in section 5.6 different PUCCH resources for ACK and NACK. |
| Samsung | Low.  Unclear why a UE would transmit ACK at all then. This is essentially single-PDSCH based HARQ-ACK feedback. Besides, it requires unnecessary PUCCH resources for fast NACK and original HARQ-ACK, respectively. |
| NEC | Low.  In our understanding, it can be controlled by gNB to ensure the time of the retransmission of the PDSCH not to exceed the URLLC latency requirement. |
| InterDigital | Low. This can be viewed as ACK skipping. In the described solution, the first resource to be used for “earlier NACK” can be configured for ACK/NACK (in similar way we have now in Rel-16) and the UE skips transmitting PUCCH for ACK case. |
| Nokia / NSB | Low. The proposed solution has a high chance of resulting in out-of-order HARQ-ACK delivery |
| MediaTek | Low |

## 6.5 Exclude DMRS from N1 determination to reduce HARQ-Ack delay

In [6], it is proposed to not count the DM-RS symbols for PUCCH in the N1 determination, which would allow earlier HARQ-ACK feedback.

This enhancement to reduce the PDSCH to HARQ-ACK delay by not counting the DM-RS as part of the N1 processing time is supported by the following companies:

* MTK [6]

**FL request 6.5: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: MediaTek**
* **Medium:**
* **Low: DOCOMO, vivo, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low |
| vivo | Low. It cannot be applied to all PUCCH formats. This method changes the PUCCH format structure and may have impacts on the multiplex capacity to multiplex different UEs by TD-OCC. In addition, the latency reduction seems low since only one- or two-OFDM symbol latency can be saved. |
| Samsung | Low, not clear on how to generate pre-computed DMRS during PDSCH decoding. Hard to provide faster UE processing time margin. |
| MediaTek | High.  It can reduce the HARQ feedback latency, and it is essential for low latency (~ms) URLLC applications. |

## 6.6 UCI multiplexing on DMRS symbols of PUSCH

In [7], 5 cases are identified where UCI multiplexing on PUSCH is not supported due to collision with DM-RS:

1. A PUCCH overlaps with 1-symbol PUSCH
2. A PUCCH overlaps with 2-symbol or 3-symbol PUSCH with frequency hopping enabled
3. HARQ-ACK on PUCCH overlaps with 4-symbol or 5-symbol PUSCH with DMRS on the last symbol without frequency hopping enabled for PUSCH
4. If frequency hopping is enabled for PUSCH and UCI is multiplexed with UL-SCH, there may not be enough REs for HARQ-ACK in the first hop in some cases.
5. If frequency hopping is enabled for PUSCH and UCI is multiplexed on PUSCH without UL-SCH, in some cases the available RE resources in the second hop is limited for CSI part 1.

The following companies suggested to support UCI multiplexing also for these (or at least a subset) of these cases:

* CATT [7]

**FL request 6.6: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: CATT**
* **Medium: MediaTek**
* **Low: DOCOMO, vivo, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. |
| vivo | Low. Above cases are all due to less symbols allocated for PUSCH transmission. Then it also not proper to support multiplex URLLC-UCI on those PUSCH due to lack of resource. |
| Samsung | Low.  The overall problem is not significant, can be avoided by other means, and would require significant HW changes. May be revisited toward the end of the WI if no other suitable solution by then, |
| LG | We have similar view to vivo. |
| MediaTek | Medium |

## 6.7 Type 1 CB size optimization considering RepNumR16

In Rel-16, the Type 1 CB construction does not take into account, that not all the TDRA entries may be configured with *RepNumR16*. This leads to larger Type 1 CB size than want is actually needed. More detailed discussions on this topic can be found in [8].

The following companies propose to support Type 1 CB size optimizations based on RepNum16:

* NEC [8]

The following potential solutions are discussed to allow Type 1 CB size optimization with respect to *RepNumR16*:

* NEC [8]:
  + Option 1: The UE determines the maximum value of all *RepNumR16* values configured in the TDRA table first, then the UE determines the semi-static HARQ-ACK codebook based on the maximum value of RepNumR16 for all entries in the TDRA table similar with slot aggregation in Rel-15.
  + Option 2: The UE determines the semi-static HARQ-ACK codebook based on the dedicated value of *RepNumR16* configured for the each corresponding entry in the TDRA table.
  + Option 2 is preferred as it can provide lower HARQ-ACK overhead.

**FL request 6.7: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: NEC**
* **Medium:**
* **Low: DOCOMO, vivo, CATT, Samsung, ZTE, Panasonic, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. |
| vivo | Low. We think it should be enhanced in MIMO session. |
| Samsung | Low.  No need for minor optimizations to Type-1 CB for URLLC. Repetitions for URLLC in the DL are also unlikely (problem is then huge on the UL). |
| NEC | It is beneficial to improve the SE. |
| LG | Low. We have same view to vivo. |

## 6.8 HARQ-Ack disabling for dynamically scheduled PDSCH

As discussed in [12], there could be cases where the HARQ-ACK feedback from the UE is of little value for the gNB due to e.g. certain latency constraints which would anyhow not enable a HARQ re-transmssions in time (Case 2 & 3 in Sec. 2.3 of [12]) or simply based on the fact that the gNB may not operate with HARQ re-transmission for certain traffic (i.e. One-shot PDSCH transmissions, Case 1 in Sec. 2.3 of [12]).

The, the following companies suggest restricting HARQ-Ack feedback for dynamically scheduled PDSCH (i.e. HARQ-ACK skipping) considering traffic latency bounds:

* OPPO [12]

**FL request 6.8: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium:**
* **Low: DOCOMO, vivo, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. This has been discussed in Rel-16 without agreement. |
| vivo | Low. share views with Sony. For dynamic PDSCH, HARQ-ACK is still useful for OLLA. |
| Samsung | Low. No/marginal benefit. |
| LG | Low. If it is an issue, we may be able to re-use solution in section 3.3 for dynamic PDSCH. |
| InterDigital | Medium. We think that the existing mechanism in NR U can be used (NNK1 value). |

## 6.9 HARQ-ACK payload size reduction (bundling / skipping)

In [13], it is discussed that for low priority HARQ-ACK to reduce the HARQ-ACK payload size bundling could be supported, whereas for high priority HARQ-ACK bundling should not be supported. As an alternative, HARQ-ACK skipping for certain PDSCH transmissions could be supported. Also [23] discussed to allow HARQ-ACK bundling to reduce the HARQ-ACK payload size.

The following companies suggest supporting HARQ-ACK bundling to reduce the HARQ-ACK payload size:

* IDC [13] (only for low priority HARQ-ACK), DCM [23]

The following companies suggest supporting HARQ-ACK skipping to reduce the HARQ-ACK payload size:

* IDC [13]

**FL request 6.9: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: DOCOMO**
* **Medium: vivo, Panasonic, NEC**
* **Low: CATT, Samsung, ZTE, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | This can be considered in AI 8.3 for cases where LP HARQ-ACK is multiplexed into HP PUCCH/PUSCH. |
| DOCOMO | This is related to following and can be discussed together   * 3.2 SPS HARQ-ACK payload size reduction / skipping * 3.3 SPS HARQ-ACK skipping for ‘skipped’ SPS PDSCH * 4.1 Type 1 HARQ-ACK codebook based on sub-slot PUCCH config |
| vivo | Low or medium. Related to other issues an also related to intra-UE multiplexing. |
| Samsung | Low.  Increase the risk to unnecessarily retransmit PDCCHs/PDSCHs just to save sometimes 1-2 HARQ-ACK bits. As URLLC will not have PDSCHs with 2 TBs, bundling will apply across different CCs (not likely to have CA) or across different time intervals (more likely) which typically have uncorrelated error events. |
| NEC | Agree with Sony and vivo. |

## 6.10 Delaying of non-latency critical HARQ-ACK

In [13], it is discussed that delay the HARQ-ACK transmissions for non-latency critical data in order to reduce the HARQ-ACK payload size or a single PUCCH transmission. In this context, non-numerical value of HARQ-ACK timing from NR-U (i.e. NN k1) is mentioned as one solution that could be adopted.

The following companies suggest supporting HARQ-ACK delaying to allow for better balancing of HARQ-ACK payload size:

* IDC [13]

As a possible solution to enabling this ‘delayed HARQ-ACK’, non-numerical value of HARQ-ACK timing from NR-U (i.e. NN k1) is mentioned by IDC [13].

**FL request 6.10: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: vivo**
* **Low: DOCOMO, CATT, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium if this is used for unlicensed URLLC taking into account priority of the HARQ-ACK. Low if this is for licensed URLLC since gNB can always schedule the PUCCH in a later sub-slot/slot. |
| vivo | Medium. NR-U mechanism can be baseline. |
| Samsung | Low.  NR-U based solutions should not be assumed transferable to non-shared spectrum as they are not implemented by corresponding UEs/gNBs and the respective markets/deployments are different. Can consider but deprioritized. |
| InterDigital | This can be viewed as an alternative to drop the low priority HARQ-ACK codebook specified in Rel-16. So instead of dropping, the low priority HARQ-ACK codebook can be delayed. NR U mechanisms can be used here. For example, in case of overlapping, the low priority HARQ CB can be considered as if NNK1 is indicated. |

## 6.11 Per SPS PDSCH repetition overriding with DG PDSCH

In [14], it is discussed, that in Rel-15, when a DG PDSCH overlaps with a SPS PDSCH in a serving cell and the timeline is satisfied, all the repetitions of the SPS PDSCH are cancelled. This may lead to SPS PDSCH performance loss if some of the repetitions are not overlapped with DG PDSCH and can be received by UE. To address this issue, in Rel-17, DG PDSCH cancels SPS PDSCH repetition can be performed per repetition. When UE receives at least one of the repetitions, UE needs to transmit HARQ-ACK for the SPS PDSCH.

The following companies suggest supporting per SPS PDSCH repetition overriding with DG PDSCH in Rel-17:

* Samsung [14]

**FL request 6.11: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:Samsung**
* **Medium: DOCOMO, vivo, NEC, Nokia/NSB**
* **Low: CATT, ZTE, Panasonic, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | High. This should be an easy fix that will improve efficient use of resource. |
| vivo | Medium. Unified behaviour between DL SPS and UL CG in terms of per repetition cancellation is desirable. It may have impacts on the timeline. |
| CATT | Our understanding of Rel-16 UE behaviour is per SPS PDSCH repetition orverriding. |
| Samsung | High.  No need to cancel all SPS PDSCH repetitions – align with the per-repetition cancelation applied in the UL of Rel-16. |
| LG | It needs to clarify current UE behavior. |
| Nokia. NSB | Medium.  Low hanging fruit: This could be easily agreeable, minor specs impact and could provide some advantages |
| MediaTek | Low |

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

In [14], it is discussed that in Rel-15, if UE multiplexes HARQ-ACK bits on PUSCH, and the number of HARQ-ACK bits is not greater than 2, UE reserves REs for up to 2 HARQ-ACK bits to avoid PUSCH decoding error due to an incorrect HARQ-ACK payload size caused by a missed PDCCH. In other words, this targets to handle vulnerability with up to 2 DG HARQ-ACK bits; 1 or 2 DG HARQ-ACK bits depending on the existence of SPS HARQ-ACK bit. In Rel-16, while such vulnerability with small number of DG HARQ-ACK bits still needs to be handled, multiple active SPS configurations and smaller SPS periodicity may result in multiple SPS HARQ-ACK bits. As a result, the incorrect HARQ-ACK payload size caused by small number of DG HARQ-ACK bits may happen for a larger number of HARQ-ACK bits when many SPS HARQ-ACK bits are present.

In this sense, the condition of 2 bits is not suitable and hence it needs enhancement, for example, introducing other threshold values than 2 bits in order to improve reliability of HARQ-ACK which could be transmitted on PUSCH.

The following companies suggest supporting to maintain the Rel-15 PUSCH reception robustness to multiplexing of 1-2 HARQ-ACK bits from dynamic scheduling also when multiple HARQ-ACK bits from SPS PDSCH are multiplexed in the PUSCH:

* Samsung [14]

**FL request 6.12: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: Samsung**
* **Medium:**
* **Low: DOCOMO, vivo, CATT, ZTE, Panasonic, NEC, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| vivo | Low. Impacts on the PUSCH performance need to be checked. |
| Samsung | High.  This is to maintain Rel-15 robustness to HARQ-ACK and PUSCH reception when there is HARQ-ACK from 1-2 DGs (as in Rel-15) but there is also HARQ-ACK from SPS PDSCH (due to the Rel-16 enhancements). |
| LG | Low. This AI is for enhancing HARQ-ACK reliability so that can remove these issues. |
| MediaTek | Low |

## 6.13 Simultaneous PUSCH & PUCCH within a cell group

Simultaneous PUCCH / PUSCH has been supported for LTE for a long time, whereas for NR simultaneous PUSCH / PUCCH is not supported. This NR short coming has been identified in and it is suggested in [19] to support simultaneous PUCCH / PUSCH in Rel-17.

The following companies suggest supporting simultaneous PUCCH and PUSCH in Rel-17:

* Pana [19] (support for different carriers, within a carrier FFS)

**FL request 6.13: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: DOCOMO, vivo, Panasonic, NEC, Nokia/NSB, MediaTek**
* **Medium: CATT, Samsung, ZTE, HW/HiSi**
* **Low:**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. |
| DOCOMO | This is also proposed in AI 8.3.3. We are fine to discuss either in AI 8.3.1.1 or AI 8.3.3 |
| vivo | High. |
| Samsung | Medium.  Conditions in NR where (a) OFDM is used and (b) PUCCH transmissions do not need to be near the cell bandwidth edges, are much easier than in LTE for supporting simultaneous PUSCH and PUCCH transmissions. RAN4 should be first consulted to provide required MPR values. |
| Panasonic | We agree with DOCOMO. |
| NEC | Agree with DOCOMO. |
| Huawei, HiSilicon | Not allowing simultaneous PUCCH and PUSCH in a cell group seems not efficient |
| Nokia, NSB | High  Nokia proposed this in Rel-16 already. This could help to reduce the required LP HARQ-ACK dropping. |
| MediaTek | High |

## 6.14 Explicit HARQ-ACK feedback for CG PUSCH

[19] discussed, that only implicit HARQ-ACK feedback has been specified for UL configured grant transmission for Rel-15. This means that there is no explicit HARQ-ACK feedback from the gNB to the UE upon receiving the UL configured grant transmission. Only when gNB is not able to successfully decode the configured grant transmission, it sends an uplink grant via DCI to the UE for retransmission. If the UE doesn’t receive anything during the duration of *ConfiguredGrantTimer*, UE assumes that the gNB has successfully received and decoded the configured grant transmission.

Based on the Rel.16 SI on URLLC, it was concluded that there is no consensus on the necessity of explicit HARQ-ACK for configured grant PUSCH in Rel.16, because at least if a configured grant PUSCH resource is not shared by multiple UEs and if the reliability requirement is to be met by a single transmission, PUSCH miss detection probability is lower than the PUSCH target BLER and in this case, gNB’s miss detection would not be the issue. On the other hand, whether more than one UE needs to be further considered or not would be one discussion point. For UL configured grant transmission, to configure completely individual resource for each UE of configured grant transmission is resource inefficient. Then, network may configure multiple UEs to share the resource. For this, explicit HARQ-ACK may be needed to support URLLC operation using CG PUSCH.

The following companies suggest supporting explicit HARQ-ACK feedback for CG PUSCH in Rel-17:

* Pana [19]

**FL request 6.14: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: DOCOMO, Samsung, Panasonic, HW/HiSi**
* **Low: vivo, CATT, ZTE, NEC, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. |
| Sharp | Medium. |
| vivo | Low. It should be discussed in URLLC support in unlicensed band session. |
| Samsung | Medium.  Implicit approach is not well suited for low latency applications. |
| Panasonic | Medium  Considering limited TU, we are OK not to prioritize this issue in Rel.17. This issue may not be the scope of “UE feedback enhancement”. To handle it in A.I. 8.3.2 is one possibility. |
| Huawei, HiSilicon | It would good if some feedback for CG-PUSCH can be introduced to do some early termination. |
| LG | We think this is out of scope, since it is not “UE feedback”. |
| Nokia, NSB | Low. Not UE really a feedback-related enhancement and already discussed in Rel-16 (although Nokia proposed it then) |
| MediaTek | Low |

## 6.15 Type 3 CB for licensed band operation

Type 3 CB (i.e. dynamic triggering for HARQ-ACK of all DL HARQ processes) has been introduced for NR-U operation in Rel-16. In [21] it is discussed, that the Type 3 CB should also be applied for licensed band operations, which includes further needed studies on the handling of the Type 3 CB with respect to different HARQ-ACK PHY priorities.

The following companies suggest supporting Type 3 HARQ-ACK CB also for licensed band URLLC operation:

* Sharp [21]

**FL request 6.15: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High: DOCOMO, vivo, NEC**
* **Medium:**
* **Low: CATT, Samsung, ZTE, Panasonic, HW/HiSi, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. |
| Sharp | High. |
| DOCOMO | This can be discussed together with 6.1 Retransmission of Canceled / Dropped Low-priority HARQ-ACK |
| vivo | High.  Should be discussed in section 6.1 Retransmission of Canceled / Dropped Low-priority HARQ-ACK? |
| Samsung | Low.  Worse HARQ-ACK BLER as HARQ-ACK payload would typically be larger than necessary, not currently supported in non-shared spectrum deployments, would require additional, NR-U like, specification changes. |
| NEC | Agree with DOCOMO and vivo that it can be discussed together with 6.1 Retransmission of Canceled / Dropped Low-priority HARQ-ACK. |
| Huawei, HiSi | From reliability perspective, it seems type 3 HARQ-ACK codebook is not so good. |
| InterDigital | High. One shot HARQ feedback can be a solution for multiple issues highlighted in this document. |
| MediaTek | Low |
| Apple | High |

## 6.16 Tri-state HARQ-ACK feedback (incl. missed PDCCH)

In [24] it is discussed, that when the gNB receives a NACK, it does actually not know if for a dynamically scheduled PDSCH the UE either missed the DL assignment or just the PDSCH decoding failed. Therefore, for the case of traditional ‘NACK’, the UE should indicate if the NACK is due to either PDSCH or if no DL assignment has been detected resulting in a Tri-state HARQ-ACK feedback:

1. ACK to indicate PDSCH decoding pass
2. NACK to indicate PDSCH decoding failure
3. CtrlFail to indicate control decoding failure/miss

The following companies suggest supporting Tri-state HARQ-ACK feedback enhancements for dynamically scheduled PDSCH:

* QC [24]

**FL request 6.16: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: Panasonic**
* **Low: DOCOMO, vivo, CATT, Samsung, ZTE, NEC, HW/HiSi, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Medium. Beneficial for PDCCH reliability. Need to consider the resource for this tri-state HARQ-ACK. |
| vivo | Low. This is not specific to URLLC. The probability of DCI miss detection should be very low for supporting URLLC. And the Tri-state HARQ-ACK feedback results in additional overhead. |
| Samsung | Low. Increased HARQ-ACK BLER due to increased payload, inapplicable for 1-2 bits HARQ-ACK (typical for URLLC), unclear what the gNB would do with the additional information as PDSCH decoding failure can be due to a number of reasons and, for the UE to be able to report, the UE already received at least one out of N PDCCHs (and, given the low PDCCH BLER, probably missed only 1 PDCCH – e.g. what would the gNB do if the UE says it received 9 PDCCHs but missed 1 PDCCH and why is that essential?). |
| Huawei, HiSi | Share similar view that it seems not URLLC specific issue, and also benefit is not clear while increasing the payload. |
| InterDigital | Low. This has the potential to increase the HARQ-ACK overhead. Instead of having one bit/TB (in case CBG based transmission is not used), 2 bits is needed. |
| MediaTek | Low |
| Apple | Medium for this specific topic. However, to carry more information for HARQ feedback in general is something we can look into, e.g. as our proposal with HARQ redundancy version sequence. |

## 6.17 PDCCH scheduling PDSCH reception is later than a PDCCH scheduling PUSCH

In [25] it is discussed that in Rel-15/16, if type-1 (semi-static) HARQ-ACK codebook is configured, the type-1 HARQ-ACK codebook can be multiplexed on PUSCH. Here, if PDCCH scheduling PDSCH reception is later than the PDCCH scheduling PUSCH, then the HARQ-ACK information for the PDSCH reception is omitted in the type-1 HARQ-ACK codebook. It is because that the generation of the PUSCH is dependent on the HARQ-ACK information in type-1 HARQ-ACK codebook. However, it blocks a UE from multiplexing the time-sensitive HARQ-ACK information in the PUSCH transmission.

Thus, the following companies suggest discussing enhancements to Type 1 CB operation for cases where PDCCH scheduling PDSCH reception is later than a PDCCH scheduling PUSCH:

* WILUS [25]

**FL request 6.17: Please provide your input on your view on priority of this issue discussed in this subsection (High / Medium / Low):**

* **High:**
* **Medium: CATT**
* **Low: DOCOMO, vivo, Samsung, ZTE, Panasonic, NEC, LG, Nokia/NSB, MediaTek**

**As well as any optional technical comments in addition (which could be maybe left for 2nd phase, if identified as high or at least medium priority).**

|  |  |
| --- | --- |
| *Company* | *View / Comments* |
| Sony | Low. This can be handled by the gNB scheduling. |
| vivo | Low. For same priority, Rel.15 rule can still be applied. While for different priorities, this operation is allowed in Rel.16, that the LP PUSCH is dropped. |
| Samsung | Low. For same priority traffic (e.g. URLLC), it is unclear why PUSCH can have larger scheduling latency than the PDSCH. |
| WILUS | High. Consider the case that HP HARQ-ACK is multiplexed on LP PUSCH (if supported in AI 8.3.3). In this case, it needs to allow HP HARQ-ACK for PDSCH scheduled by later PDCCH is multiplexed on the LP PUSH scheduled by earlier PDCCH. If timeline for HARQ-ACK multiplexing on PUSCH is satisfied, it can be supported. It can be revisited when RAN1 supports HP HARQ-ACK is multiplexed on LP PUSCH. |
| LG | Considering URLLC PUSCH has marginal scheduling delay, it is hard to meet that issue. |
| Nokia, NSB | Low. Not UE really a feedback-related enhancement and already discussed in Rel-16 (although Nokia proposed it then) |
| MediaTek | Low |

# References

1. R1-2005243 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon
2. R1-2005374 HARQ-ACK enahncements for Rel-17 URLLC vivo
3. R1-2005431 Discussion on HARQ-ACK enhancements for eURLLC ZTE
4. R1-2005513 HARQ-ACK Enhancements for IIoT/URLLC Ericsson
5. R1-2005569 HARQ-ACK enhancement to reduce retransmission time Sony
6. R1-2005633 On UE feedback enhancements for HARQ-ACK MediaTek Inc.
7. R1-2005701 UE feedback enhancements for HARQ-ACK CATT
8. R1-2005760 Enhancements on URLLC HARQ-ACK feedback NEC
9. R1-2005869 UE HARQ feedback enhancements in Release 17 URLLC/IIoT Intel Corporation
10. R1-2005929 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility
11. R1-2005967 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.
12. R1-2006058 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO
13. R1-2006070 UE HARQ-ACK feedback enhancements InterDigital, Inc.
14. R1-2006139 HARQ-ACK feedback enhancements for Rel-17 URLLC/IIoT Samsung
15. R1-2006207 Discussion on UE feedback enhancements for HARQ-ACK CMCC
16. R1-2006252 Discussion on necessity and support of physical layer feedback enhancements Spreadtrum Communications
17. R1-2006314 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics
18. R1-2006339 On the necessity and support of Rel-17 URLLC HARQ-ACK feedback enhancements Nokia, Nokia Shanghai Bell
19. R1-2006342 Discussion on UE feedback enhancements for HARQ-ACK Panasonic Corporation
20. R1-2006514 UE feedback enhancements for HARQ-ACK Apple
21. R1-2006572 UE feedback enhancements for HARQ-ACK Sharp
22. R1-2006639 Discussion on HARQ-ACK enhancements Asia Pacific Telecom co. Ltd
23. R1-2006728 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.
24. R1-2006799 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated
25. R1-2006887 Discussion on HARQ-ACK enhancement for IIoT/URLLC WILUS Inc.
26. R1-2006899 HARQ enhancement for SPS Google, Inc..

# Appendix: Summary of companies proposals

### R1-2005243 UE feedback enhancements for HARQ-ACK Huawei, HiSilicon

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

***Proposal 2*：PUCCH repetitions over sub-slots should be supported in Rel-17.**

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

***Observation 2*：Due to TSC traffic and SPS periodicity misalignment, multiple SPS configurations should be configured to serve one traffic, and the consequence is that PDSCH skipping generates unnecessary NACK feedback.**

***Proposal 3*：ACK skipping and/or NACK skipping should be supported for DL SPS in Rel-17.**

***Proposal 4*：In case of collision with invalid symbol(s) for UL transmission, HARQ-ACK postponing for DL SPS should be considered in Rel-17.**

***Proposal 5*：Dynamic PUCCH carrier switching could be considered for TDD carriers in Rel-17.**

***Proposal 6*：The following two options could be considered for power control enhancements for PUCCH in Rel-17:**

* **Option 1: Enlarging the range of TPC command for PUCCH**
* **Option 2: Dynamically indicating open-loop power control of PUCCH in DCI.**

***Observation 3*: If the gNB configures up to two code words that one DCI may schedule, the high priority HARQ-ACK codebook construction based on two code words may increase its size unnecessarily.**

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

### R1-2005374 HARQ-ACK enahncements for Rel-17 URLLC vivo

***Proposal 1: SPS*** ***HARQ-ACK feedback skipping is supported for a SPS PDSCH occasion on which there is no corresponding SPS PDSCH reception.***

***Proposal 2:*** ***UE behavior for (re)transmission of a SPS HARQ-ACK feedback in case of collision between the SPS HARQ-ACK feedback and invalid symbols should be defined to guarantee downlink SPS performance.***

### R1-2005431 Discussion on HARQ-ACK enhancements for eURLLC ZTE

***Observation 1:*** *For shorter SPS periodicities, one fixed HARQ-ACK timing value k is no longer feasible to determine a proper UL slot for transmission of HARQ-ACK associated with each DL SPS slot.*

***Observation 2:*** *HARQ-ACK (even high-priority HARQ-ACK) piggybacked on PUSCH will be dropped due to inter-UE multiplexing, which leads to numerous of re-transmissions and spectral efficiency degradation.*

***Proposal 1:*** *Indicate a set of k values where one k value for one SPS transmission in a time window configured by RRC.*

* + *RRC configures one or more sets of k values. If more than one sets are configured, one set is based on the PDSCH-to-HARQ\_feedback timing indicator field in the activating DCI.*

***Proposal 2:*** *HARQ-ACK overhead for SPS PDSCHs should be reduced.*

***Proposal 3:***  *In TDD, if UL sub-slot is configured, HARQ-ACK feedback should be enhanced to ensure a UL sub-slot can be found for HARQ-ACK transmission for PDSCH in every DL slot.*

***Proposal 4:*** *A new PUCCH or PUSCH resource for transmission of low priority HARQ-ACK to be cancelled due to intra-UE prioritization should be considered.*

***Proposal 5:*** *Re-transimission of the cancelled HARQ-ACK piggybacked on PUSCH due to inter-UE multiplexing should be considered.*

***Proposal 6:*** *Type I HARQ-ACK codebook based on sub-slot construction should be supported in Rel-17 URLLC.*

### R1-2005513 HARQ-ACK Enhancements for IIoT/URLLC Ericsson

[Observation 1 Based on Rel-16 specification related to sub-slot length for PUCCH, sub-slot PUCCH repetition is already supported, following the principle of Rel-15 PUCCH repetition across multiple slots.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709561)

[Observation 2 The existing PUCCH repetition framework is restrictive as it is only enabled by semi-static configuration and the configuration is tied to PUCCH format. Moreover, it is not applicable to sub-slot configuration of length 2 symbols.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709562)

[Observation 3 There is no need to enable back-to-back PUCCH repetition within a slot/sub-slot. To increase coverage/reliability of PUCCH transmission in a slot/sub-slot, a longer PUCCH resource can be used.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709563)

[Observation 4 When SPS occasions are over-provisioned to minimize the alignment delay to the actual transmission, there can be many unnecessary UE feedback transmission (NACK) corresponding to unused SPS occasions with no actual SPS PDSCH transmitted.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709564)

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

[Proposal 1 Support dynamic indication of PUCCH repetition in Rel-17.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709555)

[Proposal 2 Support PUCCH repetition based on UCI type.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709556)

[Proposal 3 Support PUCCH repetition of PUCCH formats 0 and 2.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709557)

[Proposal 4 For PUCCH repetition across multiple sub-slots, a PUCCH transmission in each of the sub-slots has the same resource, i.e., same starting symbol, number of symbols, and number of PRBs.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709558)

[Proposal 5 Support deferring HARQ-ACK transmission to the next UL slot/symbols when it collides with invalid slot/symbols as a result of mismatch between SPS periodicity and TDD pattern.](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709559)

[Proposal 6 Support HARQ-ACK feedback skipping for a codebook with only DL-SPS HARQ ACK feedback when all HARQ-ACK bits in the codebook are NACK,](file:///C:\Users\khugl\AppData\Local\Temp\7zO052A3497\R1-2005513%20HARQ-ACK%20Enhancements%20for%20IIoT_URLLC.docx#_Toc47709560)

### R1-2005569 HARQ-ACK enhancement to reduce retransmission time Sony

**Observation 1: Multiplexing of HARQ-ACK feedbacks for multiple PDSCHs may lead to delay in retransmission of one or more of these PDSCHs.**

**Observation 2: Providing a Fast NACK where the NACK can be transmitted earlier than the scheduled PUCCH, reduces delay in retransmission of a PDSCH.**

We therefore propose the following:

**Proposal 1: Consider a Fast NACK where a NACK for a PDSCH can be transmitted earlier than the scheduled PUCCH, whereas an ACK is transmitted at the scheduled PUCCH.**

**Proposal 2: The UE sends a Fast NACK if it fails to decode a PDSCH and the PDSCH-PUCCH delay K1 > *TDelay*.**

**Proposal 3: Fast NACK can be carried by PUCCH Format 0 or Format 1.**

### R1-2005633 On UE feedback enhancements for HARQ-ACK MediaTek Inc.

***Observation 1: The sub-6 TDD bands are widely deployed for 5G-NR. They suffer however from large latency, penalizing the URLLC deployment in these bands.***

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

***Observation 3: The UL/DL TDD pattern is the bottleneck for the URLLC latency for deployment on sub-6 TDD bands.***

***Observation 4: Dynamic cross-carrier PUCCH allows for up to 30% latency reduction.***

***Observation 5: Dynamic cross-carrier PUCCH doubles the network capacity and reduces the resource utilization compared to the Carrier Aggregation baseline operation.***

***Proposal 1: Introduce dynamic cross-carrier PUCCH for Carrier Aggregation.***

***Observation 6: PUCCH transmission using CDD reduces the missed-ACK probability.***

***Observation 7: PUCCH transmission using CDD reduces the resource utilization for retransmissions.***

***Proposal 2: Support non-transparent CDD for PUCCH transmission.***

***Observation 8: pre-computed DMRS symbol(s) can start before the UE processing timeline N1.***

***Proposal 3: Support DMRS overlap with N1 leading to latency enhancement.***

### R1-2005701 UE feedback enhancements for HARQ-ACK CATT

***Proposal 1: Support HARQ-ACK feedback enhancements for TDD DL SPS by allowing UE to delay the HARQ-ACK feedback for SPS PDSCH in case of colliding with DL symbol(s).***

***Proposal 2: Enhance sub-slot based Type-1 HARQ-ACK codebook to reduce redundant HARQ-ACK bit(s) and to include all the PDSCH occasions.***

***Proposal 3: UCI multiplexing on DMRS symbols of PUSCH should be considered in Rel-17.***

### R1-2005760 Enhancements on URLLC HARQ-ACK feedback NEC

**Proposal 1:**

* *Semi-static HARQ-ACK codebook for sub-slot based HARQ-ACK feedback procedure should be supported.*
* *The sub-slot based semi-static HARQ-ACK codebook can be determined based on following three-steps:*
  + *Step 1: Determine the HARQ-ACK multiplexing window based on the HARQ-ACK timing set and sub-slot length.*
  + *Step 2: Split the TDRA table into N sub-tables based on the sub-slot length and PDSCH-to UL sub-slot association. N is the number of sub-slot within a slot.*
  + *Step 3: Do pruning based on TDD configuration and sub-table per sub-slot similar as Rel-15.*

**Proposal 2:**

* *For a UE configured with RepNumR16 for at least one entry in the TDAR table, the UE determines the semi-static HARQ-ACK codebook based on the dedicated value of RepNumR16 configured for the each corresponding entry in the TDRA table.*

**Proposal 3:**

* *The reliability of URLLC service can be improved by enhancing the definition of DAI counters for the dynamic HARQ-ACK codebook.*

### R1-2005869 UE HARQ feedback enhancements in Release 17 URLLC/IIoT Intel Corporation

**Observation 1**

* *DL SPS HARQ-ACK may experience high dropping rate due to collisions especially when short periodicities and/or multiple SPS configurations are employed*

**Proposal 1**

* *RAN1 to prioritize work on specifying one-shot HARQ-ACK requested for a group of HARQ processes targeting DL SPS collision resolutions*
* *RAN1 to prioritize work on specifying non-numerical K1 in application to DL SPS in licensed spectrum*

**Proposal 2**

* *RAN1 to prioritize work on introducing back-to-back repetitions for short PUCCH and “relatively short” long PUCCH (e.g. 4-7 symbols)*
  + *Note, RAN1 should consider scope overlap with coverage enhancement item if PUCCH repetitions are also discussed there*

### R1-2005929 HARQ-ACK feedback enhancement for IIoT/URLLC Lenovo, Motorola Mobility

* **Observation 1: Rel-16 NR allow UE to perform multiplexing of UCI including HARQ-ACK into a PUSCH based on a slot-based multiplexing framework. Thus, low-latency HARQ-ACK feedback may not be fully realized.**
* **Proposal 1: Enhance UCI multiplexing rules including timeline requirements for effectively multiplexing sub-slot based HARQ-ACK feedback information on PUSCH**
* **Observation 2: In SPS operation for IIoT, delaying HARQ-ACK feedback beyond a certain time may not be useful, since the communication service may be considered unavailable after survival time.**
* **Proposal 2: In Rel-17, support delaying HARQ-ACK feedback for SPS PDSCH if a corresponding PUCCH resource is not available.**
* **Proposal 3: Define the maximum allowed HARQ-ACK feedback delay for a given SPS PDSCH or a set of consecutive SPS PDSCHs.**
* **Proposal 4: If UE cannot transmit HARQ-ACK information within the configured maximum HARQ-ACK feedback delay, the UE may discard the HARQ-ACK information.**

### R1-2005967 UE feedback enhancements for HARQ-ACK TCL Communication Ltd.

**Observation 1: HARQ-ACK feedback overhead will be increased due to multiple SPS configurations or shorter periodicity.**

**Proposal 1: Study solutions for reducing HARQ-ACK feedback overhead corresponding to SPS DL with shorter periodicity.**

**Proposal 2: Study HARQ-ACK skipping mechanism for shorter SPS periodicity or multiple SPS configurations.**

**Proposal 3: Further study solutions when HARQ-ACK feedback corresponding to SPS PDSCH collides with non-uplink symbols.**

**Proposal 4: To solve the collisions in TDD case, the following alternative solutions should be further studied:**

* **Option1: New HARQ-ACK feedback timing mechanism;**
* **Option2: Solutions to postpone the HARQ-ACK feedback for SPS PDSCH;**

### R1-2006058 HARQ-ACK enhancements for Rel-17 URLLC/IIoT OPPO

***Observation 1: In case of we have more concern about the impact on reliability caused by PDCCH reception, the reliability of HARQ-ACK feedback transmitted by type-1 codebook may be higher than type-2 codebook.***

***Observation 2: The payload of type-1 codebook can be optimized based on the proper configuration of K1 to guarantee the reliability of PUCCH transmission.***

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

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

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

***Proposal 3:*** ***HARQ-ACK retransmission should be supported for Rel-17 URLLC.***

***Proposal 4: One-shot HARQ-ACK transmission should be supported for Rel-17 URLLC.***

***Proposal 5: HARQ-ACK for all of available SPS PDSCHs should be reported for Rel-17 URLLC.***

***Proposal 6: If HARQ-ACK report for all of available SPS PDSCHs is supported, the HARQ-ACK codebook for SPS PDSCH can be further enhanced to achieve lower UCI overhead.***

### R1-2006070 UE HARQ-ACK feedback enhancements InterDigital, Inc.

***Observation 1:*** *An increase in HARQ-ACK payload can reduce the coverage of the feedback transmission.*

***Observation 2:*** *The effect of coverage reduction is uneven and depends on the priority of the associated transmission.*

***Proposal 1:*** *HARQ-ACK feedback reduction mechanisms should be considered for IIoT and URLLC.*

***Proposal 2:*** *HARQ-ACK feedback reduction considers the priority of the HARQ-ACK feedback.*

### R1-2006139 HARQ-ACK feedback enhancements for Rel-17 URLLC/IIoT Samsung

**Proposal 1: Consider HARQ-ACK feedback enhancements for SPS PDSCH in TDD bands.**

**Proposal 2: In Rel-17, DG PDSCH cancels SPS PDSCH repetition can be performed per repetition. When UE receives at least one of the SPS PDSCH repetitions, UE transmits HARQ-ACK for the SPS PDSCH.**

**Proposal 3: Solutions for retransmission of a dropped HARQ-ACK information can be considered pending progress on intra-UE multiplexing solutions.**

**Proposal 4: Support PUCCH repetitions using for PUCCH formats 0 and 2.**

**Proposal 5: Maintain the Rel-15 PUSCH reception robustness to multiplexing of 1-2 HARQ-ACK bits from dynamic scheduling also when multiple HARQ-ACK bits from SPS PDSCH are multiplexed in the PUSCH.**

The followings are observations of this contribution.

**Observation 1: HARQ-ACK feedback corresponding to SPS PDSCH can be often dropped in TDD bands, particularly for a short SPS PDSCH reception periodicity.**

**Observation 2: Repetitions of a PUCCH transmission over 1 or 2 symbols can maximize UL resource utilization and minimize latency for URLLC.**

### R1-2006207 Discussion on UE feedback enhancements for HARQ-ACK CMCC

**Proposal 1: Support defer HARQ-ACK for SPS PDSCH to the first available valid PUCCH resource in case it collides with downlink resources configured by TDD-UL-DL-ConfigCommon/Dedicated or downlink/SFI resources indicated by SFI.**

**Proposal 2: Support PUCCH reliability enhancements in R17 and the following options can be further investigated:**

1. **Option 1: Add some low-code rate entities to the table of maxCodeRate;**
2. **Option 2: Define two tables of PUCCH maxCodeRate for different PHY priority. The PUCCH maxCodeRate table for PHY priority 1 can be generated by adding some entries with lower code rate and removing entries with higher code rate**
3. **a beta offset can be added to maxCodeRate when determining the minimum number of PRBs for PUCCH resource for PUCCH format 2 or PUCCH format 3, or some adjustment is applied to the determined minimum number of PRBs.**

**Proposal 3: Support HARQ-ACK skipping for SPS PDSCH if gNB does not transmit the PDSCH.**

### R1-2006252 Discussion on necessity and support of physical layer feedback enhancements Spreadtrum Communications

***Proposal 1. Support sub-slot based type1 HARQ-ACK codebook in Rel-17 URLLC to further enhancement UCI reliability. Generating a separate codebook for each priority as a starting point.***

***Proposal 2. The codebook size should be constrained for sub-slot based type 1 codebook.***

***Proposal 3. Similar as Rel-16 type 1 codebook, the union set of row indexed of TDRAs are used to determine the PDSCH occasions, including for DCI formats the UE is configured to monitor PDCCH and reference of SLIV if it is configured.***

### R1-2006314 Discussion on UE feedback enhancement for HARQ-ACK LG Electronics

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

Proposal 2: Consider to support NACK only HARQ-ACK feedback based on PUCCH resource request in order for reducing PUCCH overhead.

### R1-2006339 On the necessity and support of Rel-17 URLLC HARQ-ACK feedback enhancements Nokia, Nokia Shanghai Bell

The discussions on dropping SPS HARQ-ACK due to conflicts with downlink/flexible symbols for TDD deployments can be summarized in the following observations and proposals:

* **Proposal 1: RAN1 should specify solutions to address the problem of dropping SPS HARQ-ACK feedback due to conflicts with downlink/flexible symbols for TDD deployments.**
* ***Observation 1: The options of deferring HARQ-ACK until the first available valid PUCCH resource or until the first available valid slot configured by RRC do not provide sufficient flexibility of mapping HARQ-ACK to PUCCH resource.***
* **Proposal 2: gNB indicates a set K1 containing multiple k1 values applicable to all SPS PDSCH per SPS configuration or across multiple SPS configurations. For each SPS PDSCH, the UE checks each k1 value in K1 set (e.g. in the order from left to right), and the first k1 value that results in a valid uplink PUCCH resource is selected.**

The discussions on SPS HARQ-ACK feedback reduction can be summarized in the following observations and proposals:

* ***Observation 2: For SPS PDSCH HARQ-ACK feedback reduction, ACK-only or NACK-only schemes provide limited benefits since the PUCCH resources need to be available regardless of whether the UE reports HARQ-ACK feedback or not. Also, both ACKs and NACKs would need to be anyway reported when the HARQ-ACK feedback is multiplexed with HARQ-ACK of dynamic PDSCH or of other SPS configurations to ensure aligned codebook size between gNB and UE, which leaves little benefits in terms of UE power consumption and UL interference.***
* ***Observation 3: For SPS PDSCH HARQ-ACK feedback reduction, HARQ-ACK multiplexing or bundling schemes, where HARQ-ACK information of multiple PDSCHs of a SPS configuration is transmitted on a single PUCCH, would increase the latency of HARQ-ACK reporting for dynamic PDSCH due to the need of in-order deliver of HARQ-ACK bits in a serving cell.***
* **Proposal 3: For SPS PDSCH HARQ-ACK feedback reduction, RAN1 does not further consider ACK-only/NACK-only schemes, nor HARQ-ACK multiplexing/bundling schemes due to high standardization effort and/or marginal benefits.**
* **Proposal 4: For SPS PDSCH HARQ-ACK feedback reduction, the gNB can disable HARQ-ACK feedback for one or multiple SPS configurations.**

### R1-2006342 Discussion on UE feedback enhancements for HARQ-ACK Panasonic Corporation

**Observation 1: In current Rel.16 specification, sub-slot-based PUCCH repetition is supported when the *subslotLength-ForPUCCH* is 7 symbols.**

**Proposal 1: Following enhancement should be studied in Rel.17.**

* **The PUCCH repetition of short PUCCH formats (PUCCH formats 0 or 2)**
* **The dynamic indication of the number of PUCCH repetition.**

**Proposal 2: For the system efficiency improvement, multiplexing the HARQ-ACK associated with different priorities into one PUCCH or PUSCH should be prioritized.**

**Proposal 3: HARQ-ACK retransmission could be considered as one of potential techniques for improving the system efficiency. For HARQ-ACK retransmission, if specified, the techniques specified in Rel.16 NR-U such as enhanced Type-2 HARQ-ACK codebook and/or Type 3 HARQ-ACK codebook should be a starting point.**

**Proposal 4: Simultaneous PUCCHs transmission and/or simultaneous PUCCH and PUSCH transmission could be considered as one of potential techniques for UE feedback enhancement.**

**Observation 2: Simultaneous PUCCHs or simultaneous PUCCH and PUSCH transmission in different carriers in a same PUCCH group is straightforward approach considering that Rel.15 already supports simultaneous PUSCHs in different carriers.**

**Observation 3: Whether simultaneous PUCCHs or simultaneous PUCCH and PUSCH transmission in a carrier is useful or not should be studied.**

* **If the simultaneous transmission is restricted to adjacent or almost adjacent frequency resource, the gain would be limited.**
* **How to ensure the same transmit power for all symbols and how to handle PSD difference between PUCCH and PUSCH should be taken into account.**

### R1-2006514 UE feedback enhancements for HARQ-ACK Apple

**Proposal 1: study the benefit of UE’s recommendation of a HARQ redundancy version sequence to the gNB:**

**If the UE receives the transport block correctly,**

**the UE feeds back “ACK”;**

**Else the UE feeds back a HARQ redundancy version sequence which can be indicated by assuming read-out over a basic redundancy version sequence say [0 2 3 1] with a starting version and a length .**

**Proposal 2: study the benefit of CSI feedback along with enhanced HARQ feedback**.

### R1-2006572 UE feedback enhancements for HARQ-ACK Sharp

**Proposal 1: Support Type-3 HARQ-ACK codebook corresponding to mixed priorities.**

### R1-2006639 Discussion on HARQ-ACK enhancements Asia Pacific Telecom co. Ltd

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

Observation 2 It is beneficial to allow gNB to trigger a Type-3 HARQ-ACK codebook by a DCI indicating low priority or indicating high priority.

Proposal 1 Study mechanism for retransmission of high priority HARQ-ACK codebook and low priority HARQ-ACK codebook using enhanced Type-2 HARQ-ACK codebook and Type-3 HARQ-ACK codebook as a starting point.

### R1-2006728 Discussion on HARQ-ACK feedback enhancements for Rel.17 URLLC NTT DOCOMO, INC.

**Observation 1: Repetition of short PUCCH formats and sub-slot based PUCCH repetition have possibility to reduce the latency while achieving reliability requirement**

**Proposal 1: Study repetition of short PUCCH formats and sub-slot based PUCCH repetition for reliability enhancements for HARQ feedback**

**Observation 2: Reducing UCI payload size of HARQ-ACK in a PUCCH/PUSCH has possibility to improve the reliability**

**Proposal 2: Study the reduction of UCI payload size of HARQ-ACK in a PUCCH/PUSCH for reliability enhancements for HARQ feedback, e.g., HARQ-ACK bundling**

**Observation 3: Recovery of the dropped HARQ-ACK has possibility to improve the spectral efficiency**

**Proposal 3: Study recovery of the dropped HARQ-ACK for spectral efficiency improvement**

* **One-shot (Type 3) HARQ CB specified in Rel.16 NR-U is the starting point**

### R1-2006799 HARQ-ACK enhancement for IOT and URLLC Qualcomm Incorporated

***Proposal 1:* *Investigate the types of additional information which can be transmitted jointly with Rel. 16 HARQ ACK/NACK. The potential multiple types of information can be transmitted together with HARQ-ACK in 1 stage or 2 stages.***

***Proposal 2: Support enhanced HARQ-ACK feedback including additional information (such as instantaneous CQI/MCS feedback) based on PDSCH decoding.***

***Proposal 3: Support tri-state HARQ-ACK feedback to indicate ACK for PDSCH, NACK for PDSCH, and PDCCH miss detection.***

***Proposal 4: Use MAC-CE to switch between multiple sub-slot configurations for HARQ-ACK feedback.***

***Proposal 5: Explicit HARQ-ACK feedback for SPS activation/reactivation DCIs for Type I HARQ-ACK codebook.***

***Proposal 6: SPS (re)Activation DCI can update the SPS PUCCH A/N resource.***

***Proposal 7: UE is allowed to apply DTX for skipped SPS PDSCH.***

***Proposal 8: Support ACK and NACK transmission on different PUCCH resources.***

### R1-2006887 Discussion on HARQ-ACK enhancement for IIoT/URLLC WILUS Inc.

* + ***Observation 1: HARQ-ACK information is dropped at least in the following cases:***
  + ***Case A) High priority PUSCH vs low priority PUCCH with HARQ-ACK***
  + ***Case B) High priority PUCCH with HARQ-ACK vs low priority PUCCH with HARQ-ACK***
  + ***Case C) Cancelation of PUSCH with HARQ-ACK***
  + ***Case D) Directional Collision between HARQ-ACK for SPS reception and semi-static TDD UL/DL configuration***
  + ***Proposal 1: Rel-17 should introduce solutions to avoid frequent dropping of HARQ-ACK information.***
  + ***Proposal 2: As a potential solution for A/B/C cases, consider to use type-3 HARQ-ACK codebook.*** 
    - ***FFS: size reduction and reliability of type-3 HARQ-ACK codebook***
    - ***FFS: multiplexing HARQ-ACK for SPS release DCI***
  + ***Proposal 3: As a potential solution for case D, consider to introduce autonomous HARQ-ACK resending or to multiplex the dropped HARQ-ACK information to the different HARQ-ACK information.***
  + ***Proposal 4: Further consider the case where more than one PUCCHs carrying HARQ-ACK information overlapping with a PUCCH or PUSCH.***
  + ***Proposal 5: Further consider the case where a PDCCH scheduling PDSCH reception is later than a PDCCH scheduling PUSCH.***

### R1-2006899 HARQ enhancement for SPS Google, Inc..

**Proposal: Study HARQ enhancement regarding to multiple active SPS configurations and short SPS periodicity.**