3GPP TSG-RAN WG1 Meeting #106bis-e R1-21xxxxx

e-Meeting, October 11th – 19th, 2021

Agenda Item: 8.9.2

Source: Moderator (Ericsson)

Title: Feature Lead Summary [106bis-e-LTE-Rel17-NB-IoT-eMTC-02] - final checkpoint

Document for: Discussion and Decision

# 1 Introduction

In the Work Item (WI) on “Additional enhancements for NB-IoT and LTE-MTC” [1], one of the objectives is to specify the following enhancement for LTE-MTC:

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| * Support additional PDSCH scheduling delay for introduction of 14-HARQ processes in DL, for HD-FDD Cat M1 UEs. [LTE-MTC] [RAN1] |

This feature lead summary (FLS) collects companies’ views as described in [2-6], as well as the working assumption and discussions that took place during the corresponding GTW session.

Annex 1 contains the agreements reached in RAN1 #102-e [7], RAN1 #103-e [8], RAN1 #104-e [9], RAN1 #104-bis-e [10], RAN1 #105-e [11], and RAN1 #106bis-e [12]. The FLS discussed during the first GTW session can be found in [13].

# 2 FLS on 14 HARQ processes in DL in LTE-MTC

## 2.1 Potential Agreements for Endorsement

There is a number potential agreements that have been stable (some of them even from RAN1# 106-e), thus to speed-up the progress of this Rel-17 objective it seems possible to agree on the following potential conclusion and potential agreements in a “single-shot”.

**Potential Conclusion#1:**

**Conclusion: How to implement/describe the states, e.g., table, resulting from the joint encoding solution of Alt-2e is left up to the Editor, based on the agreements for the PDSCH scheduling delay, HARQ-ACK delay and the WA confirmed for Alt-2e.**

**Potential Agreement#4:**

**The Rel-17 14 HARQ processes feature only applies to User Specific Search Space (USS)**

**Potential Agreement#5:**

**In Rel-17, for the 14 HARQ processes feature the “HARQ-ACK process number” field uses 4-bits.**

* **The mapping associated to the 4-bits of this field is updated to include the newly added HARQ processes (i.e., 11th, 12th, 13th, and 14th HARQ processes).**

**Potential Agreement#6:**

**In Rel-17, for the 14 HARQ processes feature the following updates on the technical specification are to be performed.**

* **The maximum number of received PDSCH receptions pending HARQ-ACK is set to W = 12 (in Sect. 7.3.1 of TS 36.213) when the UE is configured with 14 HARQ processes.**

Companies are kindly requested to provide their views below:

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| **Company** | **Please confirm that Potential Conclusion#1, Potential Agreement#4, #5, and #6 can be agreed.** | **Comments** |
| Lenovo, MotoM | Support |  |
| ZTE, Sanechips | Support |  |
| Ericsson | OK |  |
| Nokia, NSB | Support |  |
| Qualcomm | Support |  |

## 2.2 Open issues

In subsections below refer to set of issues that require a further discussion.

### 2.2.1 “Repetition number” field: 2 bits

Background: During the GTW session it was discussed whether the “Repetition number” field can be set to zero for the 14 HARQ processes feature as to make use of it for joint-encoding purposes. The following three options were considered:

**Potential Agreement#2:**

**In Rel-17, for the 14 HARQ processes feature the “Repetition number” field is:**

        **Opt-1: 0-bits when the “HARQ-ACK bundling flag” is set to 1 (i.e., 2-bits from this field become available for jointly-encoding purposes).**

        **Opt-2: 0-bits when the 14 HARQ processes feature is configured (i.e., 2-bits from this field become available for jointly-encoding purposes).**

        **Opt-3: 2-bits as in legacy.**

During the GTW session there were two trends, companies that think that is important to keep usable the “Repetition number” field (as per Opt-1 or Opt-3), and companies that prefer to set the “Repetition number” field to zero-bits from the moment the 14 HARQ processes feature is configured (which means that the “Repetition number” field would remain unusable as long as the 14 HARQ processes feature is configured).

Towards the end of the GTW session there was a comment questioning whether Opt-3 will require any modification on the PDSCH scheduling delay and HARQ-ACK delay expressions, the online time of the GTW session ran-out and it was no time to answer. In relation with it, below there is an illustration showing that keeping usable the “Repetition number” field will not require any additional modification.

* PDSCH scheduling delay used along with HARQ-ACK delay configured with Alt-1

1. Handling of the 11th HARQ process (associated to MPDCCH#10 and PDSCH#10) in a single HARQ process scenario without PDSCH repetition:

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| subframe # | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| MPDCCH | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| PDSCH | 12 | 13 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |  |  |  |  |  | 10 |  |  |  |  |  |  |  |
| PUCCH#  HARQ-ACK |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |  |  | 0 |  |  |  |

Note: Recall that the minimum HARQ-ACK delay that can be used encompasses 4 subframes.

Let’s focus on MPDCCH#10 & PDSCH#10:

* + The PDSCH scheduling delay is 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe.
  + The HARQ-ACK delay counting starts from subframe#18 and will be 2 BL/CE DL subframes + 1 subframe + 1 BL/CE UL subframe.

1. Handling of the 11th HARQ processes (associated to MPDCCH#10 and PDSCH#10) in a single HARQ process scenario with PDSCH repetitions.

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| subframe # | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| MPDCCH | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| PDSCH | 12 | 13 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |  |  |  |  |  | 10 | 10 | 10 | 10 |  |  |  |  |
| PUCCH#  HARQ-ACK |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |  |  |  |  |  | 0 |

Note: Recall that the minimum HARQ-ACK delay that can be used encompasses 4 subframes.

Let’s focus on MPDCCH#10 & PDSCH#10:

* + The PDSCH scheduling delay is 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe.
  + The HARQ-ACK delay counting starts from subframe#21 and will be 2 BL/CE DL subframes + 1 subframe + 1 BL/CE UL subframe.

Observations from A) and B):

* We can see how the PDSCH scheduling and HARQ-ACK delay expressions do not require any modification, since indeed the required delays are the same for a single HARQ process scenario with and without PDSCH repetition. The same conclusion applies when Alt-2e is configured.
* Keeping usable the “Repetition number” will allow us to handle situations where the radio conditions deteriorate (which is an unpredictable matter) and where the only suitable choice will be using 1 HARQ process along with PDSCH repetitions (It is worth noting that performing a reconfiguration in such scenario (as per Opt-2) is likely to fail since repetitions would be needed).
* Moreover, it is important to make clear that Opt-3 does not purse any modification on the PDSCH scheduling delay and HARQ-ACK delay, and that the PDSCH repetitions case is connected to the 1 HARQ process case.

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| **Company** | **Please state your views** | **Comments** |
| Lenovo, MotoM | Opt-2 | From the observation B, if we go ahead the timeline of scheduling HARQ process #11 and #12.... with repetition after HARQ process#10, there will be problems in HARQ-ACK delay issue. Otherwise, there will be resource waste,e.g, in subframe #21 and #22.  If repetition number field is kept as legacy, how about the HARQ-ACK bundling flag field? If we assume there is no HARQ-ACK bundling flag field if 14HARQ is configured (based on majority of companies’ feedback). That is, if 14HARQ process is configured, HARQ-ACK bundling is enabled simultaneously. If HARQ-ACK bundling is enabled, there is no MPDCCH and PDSCH repetition in legacy Rel.14(although the field of repetition number field is kept in DCI format 6-1A as HARQ-ACK bundling flag=1, we can’t configure the repetition number =2 if HARQ-ACK bundling flag=1).  RAN1#87 and RAN1#88 agreement: [R1-1706780]   * If repetition is used for MPDCCH or PDSCH, HARQ-ACK bundling is not used   If we consider PDSCH repetition to combat the channel fading, it seems there is no corresponding PUCCH with repetition to align the similar UL/DL coverage level. Because we use lots of time to get the following agreement based on the assumption that if the UE is configured with 14HARQ, the channel condition is good enough.  **Agreement**  In Rel-17, for the 14 HARQ processes feature, PUCCH repetition is not supported with HARQ-ACK bundling. |
| ZTE, Sanechips | Opt-2 | As shown in the given example, if the channel condition change cause the PDSCH repetition of HARQ process #10, similarly, more PDSCHs also would face this problem and they also should be retransmitted. Therefore, if PDSCH repetition is taken into account, this should be considered for multiple HARQ process or all the processes, which brings out the new design requirement for HARQ delay values.  14-HARQ processes feature is used for peak data rate improvement without repetition. If PDSCH supports repetition, then 14-HARQ process feature can not improve the peak data rate.  Therefore, PDSCH repetition should not be supported for 14-HARQ feature. |
| Huawei, HiSilicon | Opt-2 | When 14-HARQ processes is configured, the use of PDSCH repetition is a corner case. Anyway, if eNB really needs to schedule PDSCH repetitions, then eNB can use the common search space, there’s the fallback DCI which can be used. |
| Ericsson v013 | Opt-1 or Opt-3 | Opt-1 opens for more possibilities, and follows the legacy approach used for “DCI subframe repetition number” field. If Opt-1 were seen as more complex to implement, then Opt-3 would be our compromise because we prefer to keep the “Repetition number” field untouched rather than lossing flexibility and backward compatibility.  To Lenovo:  In the diagram B, you mentioned that after HARQ process#10 “*there will be resource waste*“, I think that what will happen afterwards will also depend on the assumption on the radio conditions at that point in time. But the question is, what will happen with Opt-2 at the moment of dealing with adverse channel conditions for HARQ process#10, a re-configuration will be required which most likely will fail because under those conditions a single HARQ processes with repetitions is basically the only suitable choice. So, Opt-2 will eventually lead to a connection loss. About your question on the “HARQ-ACK bundling flag“ field, that legacy DCI field is not under discussion therefore it will remain usable as in legacy (In our contribution we depicted an example where both bundling and no-bundling are used).  To ZTE, Sanechips:  Yes, the feature is intended to be “*used for peak data rate improvement*” but we can not assume that the radio conditions will remain invariant over time as to make always possible offering the highest peak data rate. The radio conditions can suddenly change and the intention here is simply to keep usable the legacy “Repetition number“ field to help us to deal with those situations. As I explained earlier, Opt-2 will force us to perform a re-configuration to deal with bad radio conditions, and the problem is that the re-configuration may not even go through.  About you comment on “*new design requirement for HARQ delay values*”, that is not necessary, the intention is keeping untouched the “Repetition number“ field as to be able to use it just when needed. Opt-3 does not purse any modification on the PDSCH scheduling delay and HARQ-ACK delay, the PDSCH repetitions case is connected to the 1 HARQ process case to face bad radio conditions.  To Huawei, HiSilicon:  The bad radio conditions are unpredictable and therefore can not be considered as a corner case.  About your comment “*eNB can use the common search space, there’s the fallback DCI which can be used* ”, in our understanding with CSS type 0 it is not possible to re-transmit HARQ# 8, 9, 10, 11 and 13, so CSS type 0 is not a viable fall-back. |
| Nokia, NSB | Opt-1 (slight preference)  or  Opt-2 | Having reviewed the arguements thus far, we have a **slight preference for Opt-1 now** (subject to our understanding) BUT can we can live with Opt-2 as well.  If our understanding is correct, then:   * Opt-1 fully includes Opt-2 * Opt-1 DOES NOT enable repetiton with HARQ-ACK bundling * Opt-1 avoids the issue of „***left to UE/network implementation/configuration***“ that Opt-3 could lead to … i.e. repetitions with HARQ-ACK bundling. * Opt-1 provides the added ability of a more ROBUST „repetition“ mode to 14-HARQ, that can be accessed quickly without lengthy RRC Reconfig., allowing 14-HARQ to be configured less conservatively.   The drawbacks of Opt-1 versus Opt-2 for us, include:   * Added complexity, in specs and in testing. * Potential inconsistency with the Alt-1 solution? |
| Lenovo, MotoM | Opt-2 | We strongly recommend FL to discuss the "HARQ-ACK bundling flag" field together with “Repetition number” field. It seems the discussion of “HARQ-ACK bundling flag” field is missing in 106bis FL summary. What Lenovo really cares is the UE behaviour complexity and standard impact.  For Opt.3, I am wondering what “legacy” means in “**repetition number field 2-bits as in legacy”**. In Rel.14 legacy, the repetition number field exists in DCI format 6-1A no matter HARQ-ACK bundling or non-bundling. However, the repetition number field is only available on HARQ-ACK non-bundling case. Does the “legacy” include the above understanding?  RAN1#87 and RAN1#88 agreement: [R1-1706780]   * If repetition is used for MPDCCH or PDSCH, HARQ-ACK bundling is not used   For Opt.3, if UE is configured with 14HARQ, it seems to use HARQ-ACK bundling flag to indicate the HARQ-ACK non-bundling, which field will be used to indicate the PDSCH scheduling delay and HARQ-ACK delay? Fallback DCI or new joint field? Is the whole strategy of Opt.3 similar as the following **Strategy 3** (?)  The big problems of Opt.1 are how to indicate the PDSCH scheduling delay and HARQ-ACK delay when HARQ-ACK bundling flag=0 (e.g., fallback DCI), Are you planning to have two separate UE behaviors for UE configured with 14HARQ? This is not accepted by us, especially the standard effort.  **Strategy 3:**  **If ce-14harqProcess is configured,**   * + **2-bits Repetition number field.**   + **0-bits HARQ-ACK delay field (i.e., 3-bits from this field become available e.g., for joint-encoding purposes).**   + **1-bit HARQ-ACK bundling flag.**     - **=0, 2bit DCI subframe repetition number**     - **=1, 2bit Transport blocks in a bundle**   + **5 or 7 bits New DCI field “PDSCH\_Scheduling\_Delay\_&\_HARQ-ACK\_Delay”**   **Else (i.e., If ce-14harqProcess is not configured)**   * + **2-bits Repetition number field**   + **3-bits HARQ-ACK delay field**   + **1-bit HARQ-ACK bundling flag**     - **=0, 2bit DCI subframe repetition number**     - **=1, 2bit Transport blocks in a bundle**   **End**  **Strategy 2:**  **If ce-14harqProcess is configured,**   * + **0-bits Repetition number field.**   + **0-bits HARQ-ACK delay field.**   + **0-bit HARQ-ACK bundling flag.**     - **2bit Transport blocks in a bundle**   + **5 or 7 bits New DCI field “PDSCH\_Scheduling\_Delay\_&\_HARQ-ACK\_Delay”**   **Else (i.e., If ce-14harqProcess is not configured)**   * + **2-bits Repetition number field**   + **3-bits HARQ-ACK delay field**   + **1-bit HARQ-ACK bundling flag**     - **=0, 2bit DCI subframe repetition number**     - **=1, 2bit Transport blocks in a bundle**   **End** |
| Qualcomm | Opt-3 | Our preference would be to keep legacy behavior, but after the discussion in the previous GTW we are willing to go with the majority view (our second preference would be Opt-1, though). |
| ZTE, Sanechips | Opt-2 | For eMTC , switching between Mode A and Mode B is via RRC re-configuration. We don’t see the issue for 14-HARQ RRC re-configuration when repetition is needed.  When 14-HARQ processes feature is enabled, it means larger number of HARQ processes would be scheduled. That only one of them face the bad radio conditions and this HARQ process ID is one of # 8, 9, 10, 11 and 13, is the corner case. Even if it happens, the performance still can be guaranteed by the retransmission scheduling.  For option1, we agree the analysis from Lenovo. Moreover, from our understanding, option1 provides the 3 bits HARQ delay method when HARQ bundling is not enabled. However, it does not belong to Alt-1 and alt-2e when 14-HARQ feature is configured. Therefore, opt-1 is not supported. |
| Ericsson v018 | Opt-1 or Opt-3 | To Lenovo:  About your comment “ *We strongly recommend FL to discuss the "HARQ-ACK bundling flag" field together with “Repetition number” field. It seems the discussion of “HARQ-ACK bundling flag” field is missing in 106bis FL summary.*“ Let me remind you that in RAN1# 106-e we had a potential conclusion on the “HARQ-ACK bundling flag“ field, and it was you the one that requested to remove it, indeed at that time it was mentioned that it was ok to remove the potential conclusion since the “HARQ-ACK bundling flag“ is being used as part of the options under down-selection. For RAN1# 106bis-e, potential agreements that were stable were kept.  With respect to “ *What Lenovo really cares is the UE behaviour complexity and standard impact*“, that is fine, the thing is that there are companies that on top of that also care about the backward compatibility, flexibility and assessment of scenarios that are not addressable with a semi-static approach.  About “*For Opt.3, I am wondering what “legacy” means in “repetition number field 2-bits as in legacy”.*“ The topic is about legacy candidate DCJ fields that can be set to 0-bits, when Opt-3 was drafted the wording “2-bits as in legacy“ basically means that we will not touch that legacy DCI field at all, in other words the “Repetition number“ is not a candidate DCI field to be set to 0-bits. Then you asked “*Does the “legacy” include the above understanding?: • If repetition is used for MPDCCH or PDSCH, HARQ-ACK bundling is not used*“ Yes, there is no intention of modifying the legacy behaviour, in our previous response we made clear that the PDSCH repetitions case is connected to the 1 HARQ process case (i.e., *HARQ-ACK bundling is not used*) to face bad radio conditions.  With respect to “*For Opt.3, if UE is configured with 14HARQ, it seems to use HARQ-ACK bundling flag to indicate the HARQ-ACK non-bundling, which field will be used to indicate the PDSCH scheduling delay and HARQ-ACK delay?*“ If Opt-3 is selected, then the legacy “HARQ-ACK delay“ field remains as candidate to be set to 0-bits. If it is decided that the “HARQ-ACK delay“ field is set to 0-bits from the moment the 14 HARQ process feature is configured, then we would have the new DCI field indicating jointly the “PDSCH\_scheduling\_delay\_and\_HARQ-ACK\_delay“ available as long as the feature is configured, yes it will reseemble the strategy 3 you pointed out.  About “*The big problems of Opt.1 are how to indicate the PDSCH scheduling delay and HARQ-ACK delay when HARQ-ACK bundling flag=0 (e.g., fallback DCI), Are you planning to have two separate UE behaviors for UE configured with 14HARQ? This is not accepted by us, especially the standard effort.*“ It is not a “big problem“ since basically that will be controlled by the status of “HARQ-ACK bundling flag“. When the “HARQ-ACK bundling flag“ is set to 1, then the “Repetition number“ field and “HARQ-ACK delay“ field are set to 0-bits as to contribute to built up the “PDSCH\_scheduling\_delay\_and\_HARQ-ACK\_delay“ which remain in place as long as the “HARQ-ACK bundling flag“ is to 1. On the other hand, when the “HARQ-ACK bundling flag“ is set to 0, then the “Repetition number“ field and “HARQ-ACK delay“ field are no longer set to 0-bits as to be used as in legacy, in this case the PDSCH schedling delay and HARQ-ACK delay as prior Rel-17 apply as long as the “HARQ-ACK bundling flag“ is set to 0. Opt-1 opens for more flexibility and dynamic backward compatibility.  If can not reach a consensus on Opt-1, we can only accept Opt-3 since as I mentioned earlier there are scenarios that are not addressable with a semi-static approach as per Opt-2.  To ZTE:  About “switching between Mode A and Mode B is via RRC re-configuration“, the context is different since the CE Mode re-configuration is intended to stay using that other CE Mode configuration from that moment onwards, whereas what we are discussing here occurs within the same CE Mode where the intention of keeping usable the “Repetition Number“ field is to be able to react to momentary bad radio conditions and get back to continue providing the best possible data rate once the radio condtions that were momentarely adverse are back to be good again.  With respect to “ That only one of them face the bad radio conditions and this HARQ process ID is one of # 8, 9, 10, 11 and 13, is the corner case.  Even if it happens, the performance still can be guaranteed by the retransmission scheduling.“, since the change in radio conditions is unpredicate, it is also unpredictable to know which HARQ processes are to affected. You mentioned “ Even if it happens, the performance still can be guaranteed by the retransmission scheduling“, it depends since the retransmissions may also require repetitions.  About your comment “*For option1, we agree the analysis from Lenovo*“, please see above our response to Lenovo. |

### 2.2.2 “HARQ-ACK delay” field: 3 bits

Background: In Rel-17, the HARQ-ACK delay (either based on Alt-1 or Alt-2e) will be indicated together with the PDSCH Scheduling delay through joint-encoding using a single DCI field. Thus, it is under discussion whether this legacy DCI field will be set to 0-bits depending on the status of the HARQ-ACK bundling flag, or if it will set to 0-bits from the moment the 14 HARQ process feature is configured.

**Potential Agreement#3:**

**In Rel-17, for the 14 HARQ processes feature the “HARQ-ACK delay” field is:**

         **Opt-1: 0-bits when the "HARQ-ACK bundling flag" is set to 1 (i.e., 3-bits from this field become available for jointly-encoding purposes)**

         **Opt-2: 0-bits when the 14 HARQ processes feature is configured (i.e., 3-bits from this field become available for jointly-encoding purposes).**

Companies are kindly requested to provide their views below:

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| **Company** | Please state your views | **Comments** |
| Lenovo, MotoM | Opt 2 |  |
| ZTE, Sanechips | Opt-2 |  |
| Huawei, HiSilicon | Opt-2 |  |
| Ericsson | See comment | We can be fine with Opt-2 for the “HARQ-ACK delay” field if for the “Repetition number” field Opt-3 is selected. This way we will be just setting to zero-bits the legacy DCI field that will be naturaly replaced by new joint encoding DCI field. |
| Nokia, NSB | Opt-2 |  |
| Qualcomm | Opt-2 |  |

### 2.2.3 HARQ-ACK delay set(s) for Alt-2e

Background: During the GTW session, the following Working Assumption was reached:

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| **Working Assumption**  **For the joint encoding** **of “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt-2e is configured, the HARQ-ACK delay set has a size of:**   * **Alt-C:**   + - **12 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h, i, j, k, l} for the PDSCH Scheduling delay expression associated to the delay of 2.**     - **10 elements: HARQ-ACK delay set = {o, p, q, r, s, t, u, v, x, w} for the two PDSCH Scheduling delay expressions associated to the delay of 7.**       * **FFS: The values of {a, b, c, d, e, f, g, h, i, j, k, l}, {o, p, q, r, s, t, u, v, x, w} where some of these elements may share the same value.**   **~~Note 1: The highlighted delay values in the alternatives above correspond to either range1 = {4, 5, 7, 9, 11, 13, 15, 17} or range2 = {4, 5, 6, 7, 8, 9, 10, 11}.~~**  **~~Note 2: Only one alternative under the umbrella of either Alt-A or Alt-B or Alt-C is to be selected.~~** |

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| **Company** | **Please provide your initial views on what should be the delay values for HARQ-ACK delay sets of Alt-C.** | **Comments** |
| Lenovo, MotoM |  | If HARQ-ACK delay set is 12+10+10, we should relax the support the percentage of invalid suframe to ~20%. So our preference of HARQ-ACK delay set is  {4,5,6,7,8,9,10,11,12,13,14,15}  {4,5,[6],12,13,14,15,16,17,18,[19]} |
| ZTE, Sanechips |  | For scheduling delay 2:  {4,5,6,7,8,9,10,11,12,13,15,17}  For scheduling delay 7:  {12,13,14,15,16,17,18,19,4,5} |
| Qualcomm |  | Scheduling delay of 2 – mostly reuse range1:  {4, 5, 6, 7, 9, 11, 13, 15, 17, 19}  Scheduling delay of 7:  {4, 5, 7, 9, 11, 13, 15, 16, 17, 18, 19} |
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# 3 References

1. [RP-201306](http://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_88e/Docs/RP-201306.zip), WID: Additional enhancements for NB-IoT and LTE-MTC, RAN #88e, Electronic Meeting, June 29th-3rd, 2020.
2. [R1-2108778](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2108778.zip), “Support of 14-HARQ processes in DL for HD-FDD MTC UEs,” Huawei, HiSilicon, RAN1 #106bis-e, October 11th – 19th, 2021.
3. [R1-2109315](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109315.zip), “Support of 14-HARQ processes in DL for eMTC,” Nokia, Nokia Shanghai Bell, RAN1 #106bis-e, October 11th – 19th, 2021.
4. [R1-2109338](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109338.zip), “Remaining issues on 14-HARQ processes in DL for eMTC,” ZTE, RAN1 #106bis-e, October 11th – 19th, 2021.
5. [R1-2109175](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2109175.zip), “Support of 14 HARQ processes and scheduling delay,” Qualcomm Incorporated, RAN1 #106bis-e, October 11th – 19th, 2021.
6. [R1-2110317](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2110317.zip), “Support of 14 HARQ processes in DL in LTE-MTC,” Ericsson, RAN1 #106bis-e, October 11th – 19th, 2021.
7. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #102-e, e-Meeting, August 17th – 28th, 2020.
8. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #103-e, e-Meeting, October 26th – November 13th, 2020.
9. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #104-e, e-Meeting, January 25th – February 5th, 2021.
10. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #104-bis-e, e-Meeting, April 12th – 20th, 2021.
11. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #105-e, e-Meeting, May 10th – 27th, 2021.
12. Session notes for 8.9 (Rel-17 enhancements for NB-IoT and LTE-MTC), Ad-hoc chair (Samsung), 3GPP TSG RAN WG1 Meeting #106-e, e-Meeting, August 16th – 27th, 2021.
13. [R1-2110413](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/Docs/R1-2110413.zip), “Feature Lead Summary [106bis-e-LTE-Rel17-NB-IoT-eMTC-02] - first checkpoint”, Moderator (Ericsson), RAN1 #106bis-e, October 11th – 19th, 2021.

# Annex 1

## A1.1 List of agreements from RAN1 #102-e:

**Agreement**

Introduce a new RRC configuration parameter to enable 14 HARQ processes.

**Agreement**

For a UE configured with 14 HARQ processes, a PDSCH scheduling delay of 2 BL/CE DL subframes and 7 [FFS subframes type(s)] is supported at least in the PUCCH non-repetition case:

* FFS details of signaling.
* FFS other delay values to account for the presence of non-BL/CE subframes in the PUCCH non-repetition case.
* FFS if the 14 HARQ processes feature is supported in PUCCH repetition case.

**Working Assumption**

Introduce a new optional UE capability to support 14 HARQ processes

## A1.2 List of agreements from RAN1 #103-e:

**Agreement**

The following working assumption is confirmed

Introduce a new optional UE capability to support 14 HARQ processes

**Agreement**

The design of the 14 HARQ processes feature accounts for the presence of non-BL/CE UL and DL subframes in the PUCCH non-repetition case.

* FFS: PDSCH scheduling delays
* FFS: HARQ-ACK delays
* FFS: Configurable/dynamic set of PDSCH delays/HARQ-ACK delays

**For future meetings:**

Companies to further study on the impact of measurement gaps on the 14 HARQ processes feature.

**Agreement**

For the support of 14 HARQ processes, the solution to assign PDSCH scheduling delays should be able to minimize unnecessary waste of subframes derived from the presence of non-BL/CE DL subframes and non-BL/CE UL subframes.

* The following solutions will be further investigated:
  + The indication of subframe types for the PDSCH scheduling delay of 7 are:
    - 1 BL/CE DL subframe + 1 subframe + 3 [BL/CE UL subframes] + 1 subframe + 1 BL/CE DL subframe.
    - 1 subframe + 3 [BL/CE UL subframes] + 1 subframe + 2 BL/CE DL subframes.
  + Configurable delays including other values than 2 and 7.
* Other solutions are not precluded.

**Agreement**

For the support of 14 HARQ processes, the solution to assign HARQ-ACK delays should aim to maximize the number of HARQ processes that can be scheduled in presence of non-BL/CE DL subframes and non-BL/CE UL subframes.

* Different percentages of presence of non-BL/CE subframes can be analyzed as to represent typical scenarios and determine which HARQ-ACK delays should be included.

## A1.3 List of agreements from RAN1 #104-e:

**Agreement**

The PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1):

* 2 BL/CE DL subframes.
* The PDSCH scheduling delay of 7 is expressed as:
  + 1 BL/CE DL subframe + 1 subframe + [3 subframes] + 1 subframe + 1 BL/CE DL subframe.
  + 1 subframe + [3 subframes] + 1 subframe + 2 BL/CE DL subframes.

**Agreement**

For the 14 HARQ processes feature, when PUCCH is used with 1 repetition and there is presence of non-BL/CE UL subframes (i.e., invalid UL subframes):

* The term surrounded by brackets in Solution 1 is resolved as 3 BL/CE UL subframes.

## A1.4 List of agreements from RAN1 #104-bis-e:

**Agreement**

In Rel-17, for the 14 HARQ processes feature, PUCCH repetition is not supported with HARQ-ACK bundling.

**Conclusion**

In Rel-17, the 14 HARQ processes feature is not supported when the multi-TB grant feature is enabled.

**R1-2103860** Feature Lead Summary [104b-e-LTE-Rel17\_NB\_IoT\_eMTC-02]: 2nd check point Moderator (Ericsson)

**Agreement**

In Rel-17, for the 14 HARQ process feature the HARQ-ACK delay solution will be down-selected in RAN1#105-e from:

* Alt-1: The HARQ-ACK delay is determined through an expression consisting of different subframe types (Using a similar principle as the PDSCH scheduling delay).
  + FFS: The expression consisting of different subframe types.
  + FFS: Signaling Details.
* Alt-2: The HARQ-ACK delay is determined following the legacy approach. That is, the “HARQ-ACK delay” is kept expressed in terms of “absolute subframes”.
  + FFS: The percentage of presence of non-BL/CE DL subframes and non-BL/CE UL subframes to be handled.
  + FFS: HARQ-ACK delay values and length of the HARQ-ACK delay set.
  + FFS: Signaling Details.

The following aspects will be considered towards the down-selection of one of the two alternatives (i.e., Alt-1 or Alt-2) for the HARQ-ACK delay solution:

1. Total number of bits required in DCI
2. Scenarios that can be handled, including:

(a) different numbers of scheduled HARQ processes per burst (including dynamically switching between more than 10 HARQ processes and 10 or less HARQ processes)

(b) different % of invalid subframes for both 10 and 40 SF long bitmaps

1. Robustness against loss of DCIs
2. Flexibility
3. RRC signaling overhead

## A1.5 List of agreements from RAN1 #105-e:

**Agreement**

In Rel-17, for the 14 HARQ process feature the HARQ-ACK delay solution will be supported with multiple solutions: Alt-1 for full flexibility and Alt-2e for support of legacy delay

Alt-1: The HARQ-ACK delay is determined through an expression consisting of different subframe types (Using a similar principle as the PDSCH scheduling delay).

* + Without using more than 6 bits
  + FFS: How to minimize the overhead by using joint encoding

Alt-2e: The HARQ-ACK delay is determined following the legacy approach. That is, the “HARQ-ACK delay” is kept expressed in terms of “absolute subframes”.

* + The HARQ-ACK delay values and the length of the HARQ-ACK delay set will be based on
    - Alt-2e: “3 bits (same as legacy)”
    - FFS: Whether HARQ delay set is to use range1 or range2

RRC signaling will be used to configure between Alt-1 and Alt-2e

FFS: Signaling details

FFS: Joint encoding

**Working Assumption**

The PDSCH scheduling delay and HARQ-ACK delay are jointly encoded in a single DCI field:

* The field uses no more than 7 bits if Alt-1 is configured.
* The field is 5 bits if Alt-2e is configured.
* FFS: Details of the joint encoding.
* FFS: Legacy DCI fields that might be re-purposed for the jointly encoded solution of Alt-1 and Alt-2e respectively.

Note: Alt-1 expresses the HARQ-ACK delay as: (y) BL/CE DL subframe + 1 subframe + (z) BL/CE UL subframes, where y = {0, 1, 2, … 11} and z = {1, 2, 3}.

**Conclusion:**

In Rel-17, for the 14 HARQ processes feature:

When the HARQ-ACK delay is configured to use Alt-1 “PUCCH using Repetition = 1 is postponed”, whereas when the HARQ-ACK delay is configured to use Alt-2e “PUCCH using Repetition = 1 is not postponed (legacy behavior)”.

**Agreement**

In Rel-17, the 14 HARQ processes feature is applicable for HD-FDD Cat M1 UEs in CE Mode A only.

**For discussion in future meetings:**

Whether 14 HARQ processes feature can be enabled for PDSCH repetition case

## A1.6 List of agreements from RAN1 #106-e:

Agreement

Confirm the below Working Assumption for Alt-2e with following updates

The PDSCH scheduling delay and HARQ-ACK delay are jointly encoded in a single DCI field:

* The field is 5 bits if Alt-2e is configured.
* FFS: Details of the joint encoding.
* FFS: Legacy DCI fields that might be set to zero bits in length for the jointly encoded solution Alt-2e.

For Alt-1, it will be separate discussion based existing working assumption

Agreement

Confirm the below Working Assumption for Alt-1 with following updates

The PDSCH scheduling delay and HARQ-ACK delay are jointly encoded in a single DCI field:

* The field is no more than 7 bits if Alt-1 is configured.
* FFS: Details of the joint encoding.
* FFS: Legacy DCI fields that might be set to zero bits in length for the jointly encoded solution Alt-1.

Note: Alt-1 expresses the HARQ-ACK delay as: (y) BL/CE DL subframe + 1 subframe + (z) BL/CE UL subframes, where y = {0, 1, 2, … 11} and z = {1, 2, 3}.

Agreement

For the PDSCH scheduling delay and HARQ-ACK delay jointly encoded in a single DCI field:

* The DCI field uses 7 bits if Alt-1 is configured.

Conclusion

How to implement/describe the states, e.g., table, resulting from the joint encoding solution of Alt-1 is left up to the Editor, based on the agreements for the PDSCH scheduling delay, HARQ-ACK delay and the WA confirmed for Alt-1.