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

e-Meeting, August 16th – 27th, 2021

Agenda Item: 8.9.2

Source: Moderator (Ericsson)

Title: Feature Lead Summary [106-e-LTE-Rel17\_NB\_IoT\_eMTC-02]

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:

|  |
| --- |
| * 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], classifies technical areas according with the contents in the contributions, and provides potential agreements.

Annex 1 contains the agreements reached in RAN1 #102-e [7], RAN1 #103-e [8], RAN1 #104-e [9], RAN1 #104-bis-e [10], and RAN1 #105-e [11].

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

## 2.1 “PDSCH scheduling delay” and “HARQ-ACK delay” using Alt-1

### 2.1.1 DCI field size when Alt-1 is configured

Background: In RAN1 #106-e, the Working Assumption (WA) for Alt-1 was confirmed with the following updates:

|  |
| --- |
| 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}. |

Once the WA for Alt-1 has been confirmed, RAN1 needs to decide whether 7-bits or less bits will be used for the jointly encoding solution. In relation with it, the table below provides a one-on-one comparison of the proposed solutions.

**Table 1**: **Indication of the “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt1-e is configured as in [2-6].**

|  |  |
| --- | --- |
| **General Description** | **Joint Encoding into a single DCI field**The “PDSCH Scheduling delay” and the “HARQ-ACK delay” are jointly encoding into a single DCI field. |
| **7-bits Fully Flexible Joint Encoding as in [2]:**PDSCH Scheduling delay & HARQ-ACK delay field: 7-bits.Fully-flexible solution consisting of 108 states. Table 1 in [2] depicts three groups of 36 states each.36+36+36 = 108 states utilized out of 128 states availableTotal Number of bits: 7-bits | **7-bits Fully Flexible Joint Encoding as in [3]:**PDSCH Scheduling delay & HARQ-ACK delay field: 7-bits.Fully-flexible solution consisting of 108 states. Table 1 in [3] depicts three groups of 36 states each.36+36+36 = 108 states utilized out of 128 states availableTotal Number of bits: 7-bits | **5-bits Non-Flexible Joint Encoding as in [4]:**PDSCH Scheduling delay & HARQ-ACK delay field: 5-bits.Non-flexible solution consisting of 20 states.• For the PDSCH scheduling delay = 2: When y = {8, 9, 10, 11}, then z = {1} When y = {4, 5, 6, 7}, then z = {2} When y = {0, 1, 2, 3}, then z = {3}• For the PDSCH scheduling delay = 7: y = {8, 9, 10, 11} and z = {1}12+4+4 = 20 states utilized out of 32 states availableTotal Number of bits: 5-bits | **7-bits Fully Flexible Joint Encoding as in [5]:**PDSCH Scheduling delay & HARQ-ACK delay field: 7-bits.Fully-flexible solution consisting of 108 states. (3 PDSCH Scheduling delay expressions using each the 36 possible combinations from the HARQ-ACK delay expression), indicated through the following index:IDCI = IHARQ-Delay + 11 IPDSCH-DelayIDCI spans from 0, 1, 2, … till 107.36+36+36 = 108 states utilized out of 128 states availableTotal Number of bits: 7-bits | **7-bits Fully Flexible Joint Encoding as in [6]:**PDSCH Scheduling delay & HARQ-ACK delay field: 7-bits. Fully-flexible solution consisting of 108 states. 36+36+36 = 108 states utilized out of 128 states availableTotal Number of bits: 7-bits **6-bits Pseudo-Flexible Joint Encoding as in [6]:**PDSCH Scheduling delay & HARQ-ACK delay field: 6-bits. Pseudo-flexible solution consisting of 60 states• For the PDSCH scheduling delay = 2: y = {0, 1, 2, … 9} and z = {1, 2, 3} • For the PDSCH scheduling delay = 7: When y = {2, … 11}, then z = {1} When y = {1}, then z = {1, 2} When y = {0}, then z = {1, 2, 3}30+15+15 = 60 states utilized out of 64 states availableTotal Number of bits: 6-bits |
| **Pros** | * Covers all possible cases (i.e., 108 states) we can have with the variables “y” and “z” in the “HARQ-ACK delay expression” used along with the three possible PDSCH Scheduling delay expressions.
 | * Reduces the size of the DCI field at the cost of letting unaddressed several scenarios.
 | * Covers all possible cases (i.e., 108 states) we can have with the variables “y” and “z” in the “HARQ-ACK delay expression” used along with the three possible PDSCH Scheduling delay expressions.
 | 7-bits Fully-Flexible solution:* Covers all possible cases (i.e., 108 states) we can have with the variables “y” and “z” in the “HARQ-ACK delay expression” used along with the three possible PDSCH Scheduling delay expressions.

6-bits Pseudo-Flexible solution:* Provides a 1-bit reduction with respect to a Fully-Flexible solution by using 30 + 15 + 15 = 60 states. According with [6], the design was carefully selected as to cover “any legacy scenario spanning from having only 1 HARQ process present until up to 10 HARQ processes present, as well as the new Rel-17 scenarios consisting of 14 HARQ processes” letting unaddressed only corner-case scenarios such as the one depicted in a) in Annex 1 of [6].
 |
| **Cons** | * Depending on how many legacy can be re-purposed, the DCI size might be required to be increased by several bits. Nonetheless, if for example at least 5-bits could be re-purposed then the DCI would be required to be increased by just 2-bits.
 | * With only 20 states, this joint encoding design is unable to address scenarios where there are few HARQ processes in use.
 | * Depending on how many legacy can be re-purposed, the DCI size might be required to be increased by several bits. Nonetheless, if for example at least 5-bits could be re-purposed then the DCI would be required to be increased by just 2-bits.
 | * Depending on how many legacy can be re-purposed, the DCI size might be required to be increased by several bits. Nonetheless, if for example at least 5-bits could be re-purposed then the DCI would be required to be increased by just 1-bit.
 |

During the GTW session on 14 HARQ processes, one company (which proposal can be found in [4], see Table 1) requested to keep open the exact number of bits to be used for the jointly encoding of Alt-1. Based on the majority views, the following proposal is made:

**Potential Agreement#1:**

**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.**

|  |  |  |
| --- | --- | --- |
| **Company** | **OK with Potential Agreement#1?** | **Comments**  |
| Qualcomm | Yes |  |
| Nokia, NSB | Yes |  |
| Ericsson | Yes |  |
| FUTUREWEI | Yes |  |
| Lenovo, MotoM | Yes |  |

### 2.1.2 Implementation of Alt-1 into the technical specifications

In Table 1, we can see that there are several proposals on how to implement the states resulting from the jointly encoding of Alt-1, which can be based on an equation [2] or a table [3], [5]. In the view of the Feature Lead, the implementation of the joint encoding solution can be left up to the Editor of TS 36.213, since it is enough knowing that there are three PDSCH scheduling delay expressions, “y” and “z” in the HARQ-ACK delay expression, and that all states are available if 7-bits are used for the joint encoding of Alt-1. Thus, aiming at progressing towards the completion of this feature, the following note is suggested to be captured into the Chairman’s notes:

**Potential Note#1:**

**Note: How to implement/describe the states resulting from the joint encoding solution of Alt-1 is left up to the Editor of TS 36.213, based on the agreements for the PDSCH scheduling delay, HARQ-ACK delay and the WA confirmed for Alt-1.**

|  |  |  |
| --- | --- | --- |
| **Company** | **OK with Note#1?** | **Comments**  |
| Qualcomm |  | No strong view either way, in the end the CRs have to be approved by RAN1. |
| Nokia, NSB | OK | Agree with FL assessment.  |
| Ericsson | OK | The states resulting from the joint encoding can be equally described either using an Equation or a Table.* Equation-based approach as in [5]

$$I\_{DCI}=y+12\left(z-1\right)+36I\_{PDSCH-Delay}$$* + $I\_{PDSCH-Delay}=$ **0: 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe.**
	+ $I\_{PDSCH-Delay}=$ **1 : 1 subframe + 3 BL/CE UL subframes+ 1 subframe + 2 BL/CE DL subframes.**
	+ $I\_{PDSCH-Delay}=$ **2: 2 BL/CE DL subframes.**

Given that:y ∈ {0,…,11}z ∈ {1,2,3}IPDSCH-Delay ∈ {0,1,2}Then:IDCI = 0 + 12(1-1) + 36(0) = 0 would mean:HARQ-ACK delay = 0 BL/CE DL subframe + 1 subframe + 1 BL/CE UL subframesPDSCH Scheduling delay = 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframeIDCI = 1 would mean:HARQ-ACK delay = 1 BL/CE DL subframe + 1 subframe + 1 BL/CE UL subframesPDSCH Scheduling delay = 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframeand so on ... until index IDCI = 107.* Table-based approach as below or as in [2], [3].

|  |  |  |
| --- | --- | --- |
| PDSCH scheduling delay and HARQ-ACK delay field | PDSCH scheduling delay | HARQ-ACK delay |
| 0 | 2 BL/CE DL subrames | Y = 0 , z = 1HARQ-ACK delay = 0 BL/CE DL subframe + 1 subframe + 1 BL/CE UL subframes  |
| 1 | Y = 1, z = 1HARQ-ACK delay = 1 BL/CE DL subframe + 1 subframe + 1 BL/CE UL subframes |
| ... |
| 107 | 1 subframe + 3 BL/CE UL subframes+ 1 subframe + 2 BL/CE DL subframes | Y = 11, z = 3HARQ-ACK delay = 11 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes |

Due that the most important is captured all the available states regardless of whether they are described through a table or an equation, as to make a more efficient use of the online and offline time, we tend to think is better to left the implementation/description of the states resulting from the joint encoding solution of Alt-1 up to the Editor of TS 36.213. |
| FUTUREWEI | OK with a new DCI field and table left to the editors | To make the joint coding solution solution as clean and easy to understand as possible we suggest:1. Setting fields to zero bits in length (as applicable)
2. Adding a new field to the DCI in 212 called e.g „Delays for PDSCH Scheduling and HARQ-ACK“ that is either 5 or (up to) 7 bits in length, and include the reference to the appropriate (new) tables.

If the tables are in 212 they would have PDSCH scheduling delay and HARQ-ACK delay columns and 213 would refer directly to those variables. If in 213 then 212 would just point to 213. |
| Lenovo, MotoM | OK | Share the view as FUTUREWEI. TS36.212 can list the new fields and further details table can be captured in 212 or 213. We can give the editor a reference in this email discussion, e.g., table below or the table from Huawei and Nokia contribution.

|  |  |  |
| --- | --- | --- |
| Delays for PDSCH Scheduling and HARQ-ACK field mapped to index | PDSCH scheduling delay | HARQ-ACK delay |
| y | z |
| 0 | 0 | 0 | 1 |
| … | … | … | … |
| 11 | 0 | 11 | 1 |
| 12 | 0 | 0 | 2 |
| … | … | … | … |
| 23 | 0 | 11 | 2 |
| 24 | 0 | 0 | 3 |
| … | … | … | … |
| 35 | 0 | 11 | 3 |
| 36 | 1 | 0 | 1 |
| … | … | … | … |
| 47 | 1 | 11 | 1 |
| 48 | 1 | 0 | 2 |
| … | … | … | … |
| 59 | 1 | 11 | 2 |
| 60 | 1 | 0 | 3 |
| … | … | … | … |
| 71 | 1 | 11 | 3 |
| 72 | 2 | 0 | 1 |
| … | … | … | … |
| 83 | 2 | 11 | 1 |
| 84 | 2 | 0 | 2 |
| … | … | … | … |
| 96 | 2 | 11 | 2 |
| 96 | 2 | 0 | 3 |
| … | … | … | … |
| 107 | 2 | 11 | 3 |
| 108-127 | Reserved States |

 |

## 2.2 “PDSCH scheduling delay” and “HARQ-ACK delay” using Alt-2e

### 2.2.1 HARQ-ACK delay set for Alt-2e

Background: In RAN1 #106-e, the Working Assumption (WA) for Alt-2 was confirmed with the following updates:

|  |
| --- |
| **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** |

Once the WA for the joint encoding of Alt-2e has been confirmed, RAN1 needs to decide what will be the size of the HARQ-ACK delay set and the delay values it contains. In relation with it, Table 2 compares one-on-one the joint encoding solutions as described in [4-6]:

**Table 2**: **Joint Encoding indication of the “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt2-e is configured as in [4-6].**

|  |  |
| --- | --- |
| **General Description** | **Proposed Solutions: “PDSCH Scheduling delay” and “HARQ-ACK delay” jointly encoded into a single DCI field** |
| **Joint Encoding as in [6]:**PDSCH Scheduling delay & HARQ-ACK delay field: 5-bits (3 PDSCH Scheduling delay expressions using each the same 10 values in the HARQ-ACK delay set)10+10+10 = 30 states utilized out of 32 states availableTotal Number of bits: 5-bits | **Joint Encoding as in [5]:**PDSCH Scheduling delay & HARQ-ACK delay field: 5-bits (3 PDSCH Scheduling delay expressions using respectively 11, 11, and 10 values in the HARQ-ACK delay set) indicated through the following index:IDCI = IHARQ-Delay + 11 IPDSCH-DelayIDCI spans from 0, 1, 2, … till 31.10+11+11 = 32 states utilized out of 32 states availableTotal Number of bits: 5-bits | **Joint Encoding as in [4]:**PDSCH Scheduling delay & HARQ-ACK delay field: 5-bits (3 PDSCH Scheduling delay expressions using respectively 14, 8, and 8 values in the HARQ-ACK delay set)14+8+8 = 30 states utilized out of 32 states availableTotal Number of bits: 5-bits |
| **Pros** | * Balanced HARQ-ACK delay set size:

The HARQ-ACK delay set will have the same size for all the PDSCH Scheduling delay Expressions. That is, the size of the HARQ-ACK delay set is 10 for the PDSCH scheduling delay expression associated to the delay of 2, as well as for the two PDSCH scheduling delay expressions associated to the delay of 7. | * Fully exploits the 32 states available with 5-bits.
 | N/A |
| **Cons** | * Only exploits 30 states out of the 32 states available with 5-bits.
 | * Unbalanced HARQ-ACK delay set size:

The HARQ-ACK delay set will have a different size depending on the PDSCH Scheduling delay Expression. That is, the size of the HARQ-ACK delay set is 10 for the PDSCH scheduling delay expression associated to the delay of 2, whereas the HARQ-ACK delay set is 11 for the two PDSCH scheduling delay expressions associated to the delay of 7. | * Only exploits 30 states out of the 32 states available with 5-bits.
* Unbalanced HARQ-ACK delay set size:

The HARQ-ACK delay set will have a different size depending on the PDSCH Scheduling delay Expression. That is, the size of the HARQ-ACK delay set is 14 for the PDSCH scheduling delay expression associated to the delay of 2, whereas the HARQ-ACK delay set is 8 for the two PDSCH scheduling delay expressions associated to the delay of 7.* The limited HARQ-ACK delay set size for the two PDSCH scheduling delay expressions associated to the delay of 7, may not make possible to handle scenarios using few HARQ processes (Recall that the number of HARQ processes changes dynamically via DCI).
 |

**Potential Agreement#2:**

**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:**

**Opt-1:**

**10 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h, i, j} equally applicable for each of the three PDSCH Scheduling delay expressions.**

* + **FFS: The values of a, b, c, d, e, f, g, h, i, j.**

**Opt-2:**

**10 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h, i, j} for the PDSCH Scheduling delay expression associated to the delay of 2.**

**11 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h, i, j, k} 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.**

**Opt-3:**

**14 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h, i, j, k, l, m, n} for the PDSCH Scheduling delay expression associated to the delay of 2.**

**8 elements: HARQ-ACK delay set = {a, b, c, d, e, f, g, h} 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, m, n.**

|  |  |  |
| --- | --- | --- |
| **Company** | **For the Potential Agreement#2, please state your views on whether you prefer:****Opt-1 or Opt-2 or Opt-3**  | **Comments**  |
| Qualcomm | Opt-2 | Not a very strong view, though, we may be OK with the other approaches as well. |
| Nokia, NSB | Opt-2 | Have a slight preference for Opt-2, because it appears to use all the available 32 states, which hopefully means it provides the scheduler with greater flexibility. |
| Ericsson | Opt-1 | We prefer to have a single (and same) HARQ-ACK delay set available for all the PDSCH Scheduling delay expressions. |
| FUTUREWEI |  | We were OK with the same 8 values associated with each of the 3 delay expressions so can probably live with any option. OK to agree to at least 8 for each and have some number as reserved (or FFS for next meeting) also. |
| Lenovo, MotoM | Slightly prefer Opt-2 or 3 | Bacause there are higher probablity of the PDSCH schedulding delay of 2, so we should give more HARQ-ACK delay flexibitlity for PDSCH scheduling delay of 2. |
|  |  |  |
|  |  |  |

### Implementation of Alt-2e into the technical specifications

In Table 2, we can see that there are several proposals on how to implement the states resulting from the jointly encoding of Alt-2-e, which can be based on an equation [2] or a table [4]. In the view of the Feature Lead, the implementation of the joint encoding solution can be left up to the editor of TS 36.213, since it is enough knowing that there are three PDSCH scheduling delay expressions, the size of HARQ-ACK delay set, and that 5-bits are used for the joint encoding of Alt-2e. Thus, aiming at progressing towards the completion of this feature, the following note is suggested to be captured into the Chairman’s notes:

**Potential Note#2:**

**Note: How to implement/describe the states resulting from the joint encoding solution of Alt-2e is left up to the Editor of TS 36.213, based on the agreements for the PDSCH scheduling delay, HARQ-ACK delay and the WA confirmed for Alt-2e.**

|  |  |  |
| --- | --- | --- |
| **Company** | **OK with Note#2?** | **Comments**  |
| Qualcomm |  | Same as comment as for note#1 |
| Nokia, NSB | OK | Agree with FL assessment. |
| Ericsson | OK | Same reasons as in our comment for Note#1. |
| FUTUREWEI | OK with a new DCI field and table left to the editors | See our comment for Note #1. Our preference is to handle Alt 1 and Alt 2e in as similar a manner as possible from a spec perspective as possible (i.e, one new field of 5 or 7 bits refering to the respective new tables). |
| Lenovo, MotoM | OK | We hope to handle the two alternatives in the same manner as comements by FUTUREWEI. We can give the editor a reference in this email discussion, e.g., table below.

|  |  |  |
| --- | --- | --- |
| Delays for PDSCH Scheduling and HARQ-ACK field mapped to index | PDSCH scheduling delay | HARQ-ACK delay*k0* |
| 0 | 0 | 4 |
| … | … | … |
| 13 | 0 | 17 |
| 14 | 1 | x |
| … | … |  |
| 21 | 1 | x |
| 22 | 2 | x |
| … | … | … |
| 29 | 2 | x |
| 30-31 | Reserved States |

 |

## 2.3 Usage of DCI fields in Format 6-1A

Background: To indicate the “PDSCH scheduling delay” and “HARQ-ACK delay” there is a need to find out whether some existing DCI fields can be set to zero for the 14 HARQ processes feature as to make use of them for other purposes (e.g., jointly-encoding), which will help to do not have to drastically increase the DCI size. The sub-sections below list each of the DCI fields mentioned in [2-6].

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

Background: In RAN1 #105-e, the following was noted in relation with the PDSCH repetition associated to the 2-bits “repetition number” field:

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| --- |
| **For discussion in future meetings:**Whether 14 HARQ processes feature can be enabled for PDSCH repetition case |

The table below collects the views that companies have about the usage of the “2-bits: Repetition number” field as in [2-6].

|  |  |
| --- | --- |
| **Company** | **“Repetition number” field: Compendium of views on the DCI fields that may be re-purposed [2-6].** |
| **Huawei, HiSilicon [2]** | **Proposal 3: The 2 bits in repetition field for 14 HARQ processes can be repurposed to indicate PDSCH scheduling delay if Alt-2e is configured.****Proposal 4: The repetition field, HARQ-ACK delay field can be re-puposed to jointly indicate the PDSCH scheduling delay and the HARQ-ACK delay if Alt-1 is configured.** |
| **ZTE [4]** | **Proposal 1: The PDSCH repetition number is assumed to be 1 if 14-HARQ processes feature is enabled.*****Proposal 3: For HARQ-ACK solution Alt-2e, legacy 2-bit ‘Repetition number’ field and 3-bit ‘HARQ-ACK delay field’ in DCI format 6-1A can be repurposed to indicate the 5-bit ‘PDSCH scheduling delay and HARQ-ACK delay’ field.**** ***HARQ-ACK delay value in absolute subframes would be {4~17} when PDSCH scheduling delay is 2.***
* ***HARQ-ACK delay value in absolute subframes would be {12~19} when PDSCH scheduling delay is 7.***

***Proposal 4: For HARQ-ACK solution Alt-1, legacy 2-bit ‘Repetition number’ field and 3-bit ‘HARQ-ACK delay field’ in DCI format 6-1A can be repurposed to indicate the 5-bit ‘PDSCH scheduling delay and HARQ-ACK delay’ field.**** ***For PDSCH scheduling delay of 2, the value set y can be fixed for a certain z.***
	+ - * ***y would be {8, 9 10, 11} BL/CE DL subframes for z = 1 BL/CE UL subframe***
			* ***y would be {4, 5, 6, 7} BL/CE DL subframes for z = 2 BL/CE UL subframes***
			* ***y would be {0, 1, 2, 3} BL/CE DL subframe(s) for z = 3 BL/CE UL subframes***
* ***For PDSCH scheduling delay of 7, the value z would be 1 BL/CE UL subframe which corresponds to {8, 9 10, 11} BL/CE DL subframes.***
 |
| **Qualcomm Incorporated [5]** | **Proposal 4: Do not introduce optimizations for the support of PDSCH repetition.** |
| **Ericsson [6]** | Observation 10: Re-purposing the 2-bits of the “repetition number” field is feasible using the same approach used for the “DCI subframe repetition” field which does not allow to use MPDCCH repetitions along with HARQ-ACK bundling when the "HARQ-ACK bundling flag" is set to 1.Proposal 1: In Rel-17 for the 14 HARQ processes feature, the bits of the following fields in DCI format 6-1A are repurposed when the "HARQ-ACK bundling flag" is set to 1:3-bits of the “HARQ-ACK delay” field2-bits of the “Repetition number” field |

According with [2-6], three companies propose that the “Repetition number field” [2], [4], [6] is 0-bits for the 14 HARQ processes feature as to make use of the 2-bits of this field for other purposes, nonetheless one of them (i.e., [6]) mentions that only when the “HARQ-ACK bundling flag” is set to 1 (to follow a legacy principle). On the other hand, one company [5], does not support changes on the “2-bits: Repetition number field”.

**Potential Agreement#3:**

**The “Repetition number” field is:**

* **Option 1: 0-bits [when the "HARQ-ACK bundling flag" is set to 1] (i.e., 2-bits from this field become available e.g., for jointly-encoding purposes)**
* **Option 2: 2-bits (i.e., This field remains as in legacy)**

|  |  |  |
| --- | --- | --- |
| **Company** | The“Repetition number” field is:Option 1: 0-bits [when the "HARQ-ACK bundling flag" is set to 1] (i.e., 2-bits from this field become available e.g., for jointly-encoding purposes)OrOption 2: 2-bits (This field remains as in legacy) | **Comments**  |
| Nokia, NSB | Opt 1 | We would go a step further (discussed later) and also repurpose the bundling flag, which in our view, is implied by the comment |
| FUTUREWEI | Opt 1 (without using the term repurposed) | The term repurpose is unclear, if there is a 2 bit field that is replaced with another 2 bit field then perhaps it is OK, but as some joint coding options with various sizes are being considered it is best for now to directly state that these legacy fields are of zero size rather than use the term repurpose. |
| Lenovo, MotoM | Opt 1(?) | Share the similar view as FUTUREWEI. |
| Feature Lead | See comment | To Futurewei, the use of the word “Repurpose” was just a way to express it in a shortly manner (In detail I think we all know what we mean). Otherwise, the titles, options, etc across the subsections may end up being excessively long.Making an effort to address your comment, the word “Repurpose” has been removed, and a side effect the wording in the potential agreements acrosss section 2.3 has been updated. |
| Ericsson | Opt-1 | Opt-1 only if it is subject to the condition of having the "HARQ-ACK bundling flag" set to 1.This is to follow the same principle used in legacy, where the “DCI subframe repetition number” field is 0 bits if “Transport blocks in a bundle” is present which in turn depends on the "HARQ-ACK bundling flag" to be set to 1. |
| Huawei, HiSilicon | Opt 1 | The repetition field is not needed since it is not utilized for 14-HARQ processes.  |
| ZTE, Sanechips | Opt 1 | From the perspective of peak data rate, the PDSCH repetition number is assumed to be 1 if 14-HARQ processes feature is enabled. |
| Qualcomm | Same as legacy | Agree with Ericsson. Just to recap, how it works is as follows:- HARQ ACK bundling flag set to 1 🡺 MPDCCH is not repeated, 2 bits indicate TB in bundle.- HARQ ACK bundling flag is set to 0 🡺 2 bits indicate MPDCCH repetition level.This behavior should be kept. |
|  |  |  |

### 2.3.2 “HARQ-ACK bundling flag” field: 1 bit

Background: One company in [3] suggests that the “HARQ-ACK bundling flag field” is 0-bits for the 14 HARQ processes feature as to make use of the 1-bit of this field for other purposes:

|  |  |
| --- | --- |
| **Company** | **“HARQ-ACK bundling flag” field: Compendium of views on the DCI fields that may be re-purposed [2-6].** |
| **Nokia, Nokia Shanghai Bell [3]** | **Proposal 5: When the 14-HARQ process scheme (Alt. 1 or 2e) is configured, then the 1 DCI bit reserved for the HARQ-ACK bundling flag is repurposed.** |

Given the single company view:

**Potential Conclusion#1:**

**The 1-bit of the “HARQ-ACK bundling flag” field remains used as in legacy**

Companies are kindly requested to provide their views below:

|  |  |  |
| --- | --- | --- |
| **Company** | The 1-bit of the “HARQ-ACK bundling flag” field remains used as in legacy.OK? | **Comments**  |
| Nokia, NSB | OK | ~~Unless there is a clear reason/scenario for supporting 14-HARQ without HARQ-ACK bundling, we feel this can be repurposed.~~We accept Ericsson’s explanation as to the value of maintaining this legacy field. |
| FUTUREWEI |  | Please do not use the term repurpose. May be OK to set this to zero bits. |
| Lenovo, MotoM | OK, the field is not present when 14HARQprocess |  |
| Feature Lead | See comment | To Nokia and Lenovo, your answer does not seem to in line with the comment. Maybe you can double check now that the wording has been revised. |
| Ericsson | OK | In our view we must not make 0-bits the “1-bit HARQ-ACK bundling flag” as to use this 1-bit for other purposes, since the purpose of the flag in today’s specification is to dynamic pass via DCI (i.e., without making use of a re-configuration) from using no bundling to use bundling and vice-versa. I believe companies need to recall that is also possible to dynamically change via DCI the number of HARQ processes to be used. For example, a couple of scheduling cycles may use 14 HARQ processes which require HARQ-ACK bundling, but a subsequent scheduling cycle may use a few HARQ process (e.g., 3) for which HARQ-ACK bundling is not required. We do not want to remove this flexibility from a scheduling perspective. |
| Huawei, HiSilicon | OK | This field is not needed for 14 HARQ processes. |
| ZTE, Sanechips | OK | From our perspective, the 1 bit bundling flag field is needed and should perform as the same with legacy. |
| Qualcomm | Yes | There is no need to change the HARQ-ACK bundling flag, the use can remain as legacy (see comment to the previous question) |

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

Background: Four companies propose that the “HARQ-ACK delay field” [2], [3], [4], [6] is 0-bits for the 14 HARQ processes feature as to make use of the 3-bits of this field for other purposes, one of them (i.e., [6]) additionally mentions that only when the “HARQ-ACK bundling flag” is set to 1.

|  |  |
| --- | --- |
| **Company** | **“HARQ-ACK delay” field: Compendium of views on the DCI fields that may be re-purposed [2-6].** |
| **Huawei, HiSilicon [2]** | **Proposal 4: The repetition field, HARQ-ACK delay field can be re-puposed to jointly indicate the PDSCH scheduling delay and the HARQ-ACK delay if Alt-1 is configured.** |
| **Nokia, Nokia Shanghai Bell [3]** | **“**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Existing DCI** | **Alt. 2e DCI changes** | **Alt. 1 DCI changes** |
| HARQ-ACK delay | 3 | 3 | 7 |
| New PDSCH Delay | 0 | 2 |

**”** |
| **ZTE [4]** | ***Proposal 3: For HARQ-ACK solution Alt-2e, legacy 2-bit ‘Repetition number’ field and 3-bit ‘HARQ-ACK delay field’ in DCI format 6-1A can be repurposed to indicate the 5-bit ‘PDSCH scheduling delay and HARQ-ACK delay’ field.******Proposal 4: For HARQ-ACK solution Alt-1, legacy 2-bit ‘Repetition number’ field and 3-bit ‘HARQ-ACK delay field’ in DCI format 6-1A can be repurposed to indicate the 5-bit ‘PDSCH scheduling delay and HARQ-ACK delay’ field.*** |
| **Ericsson [6]** | Proposal 1: In Rel-17 for the 14 HARQ processes feature, the bits of the following fields in DCI format 6-1A are repurposed when the "HARQ-ACK bundling flag" is set to 1:3-bits of the “HARQ-ACK delay” field2-bits of the “Repetition number” field |

**Potential Agreement#4:**

**The “HARQ-ACK delay” field is:**

* **Option 1: 0-bits [when the "HARQ-ACK bundling flag" is set to 1] (i.e., 3-bits from this field become available e.g., for jointly-encoding purposes)**
* **Option 2: 3-bits (i.e., This field remains as in legacy)**

Companies are kindly requested to provide their views below:

|  |  |  |
| --- | --- | --- |
| **Company** | The“HARQ-ACK delay” field is:Option 1: 0-bits [when the "HARQ-ACK bundling flag" is set to 1] (i.e., 3-bits from this field become available e.g., for jointly-encoding purposes)OrOption 2: 3-bits (i.e., This field remains as in legacy) | **Comments**  |
| Nokia, NSB | Opt 1 |  |
| FUTUREWEI | Depends on the Alt | Please do not use the term repurposed. In addition, this field is a bit different than the other legacy fields in that it may be the same size or extended or set to zero depending on whether joint or separate coding is used. |
| Lenovo, MotoM |  | If joint scheduling, the field is not present. |
| Ericsson | Opt-1 | If both the “HARQ-ACK delay” and “Repetition number” fields are 0-bits when the "HARQ-ACK bundling flag" is set to 1, then 5-bits in DCI would become available to implement Alt-1 and Alt-2-e respectively. |
| Huawei, HiSilicon |  | It depends on the outcome of discussion in previous sections on joint/separate encoding. |
| ZTE, Sanechips | Opt-1 | Based on our previous comments. |
| Qualcomm |  | This question seems outdated (if we jointly encode HARQ-Ack delay with PDSCH scheduling delay, of course the HARQ-ACK delay field is gone) |
| FUTUREWEI |  | Agree with Qualcomm |

## 2.4 Other topics

### 2.4.1 Search Space for the 14 HARQ processes feature

Background: In [5] and [6], the following proposals were made in relation with the search space to be used for the 14 HARQ processes feature:

|  |  |
| --- | --- |
| **Company** | **Search Space for the 14 HARQ processes feature: Compendium of views on the DCI fields that may be re-purposed [2-6].** |
| **Qualcomm Incorporated [5]** | **Proposal 5: Introduce the following specification changes for supporting 14 HARQ processes:****The PDSCH scheduling delay applies only to PDSCH scheduled from USS. The new fields in DCI do not apply to CSS**  |
| **Ericsson [6]** | Proposal 6: Rel-17 for the 14 HARQ processes feature, the User Specific Search Space (USS) is used. |

**Potential Agreement#5:**

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

Companies are kindly requested to provide their views below:

|  |  |  |
| --- | --- | --- |
| **Company** | OK with Potential Agreement? | **Comments**  |
| Nokia, NSB | OK |  |
| Lenovo,MotoM | OK |  |
| Ericsson | OK | None |
| Huawei, HiSilicon | OK |  |
| ZTE, Sanechips | OK |  |
| Qualcomm | OK |  |

### 2.4.2 “HARQ-ACK process number” field: 4 bits

Background: Two companies propose to keep using as in legacy the “4-bits: HARQ-ACK process number field” [3], and [5]:

|  |  |
| --- | --- |
| **Company** | **“HARQ-ACK delay” field: Compendium of views on the DCI fields that may be re-purposed [2-6].** |
| **Nokia, Nokia Shanghai Bell [3]** | **Proposal 6: The “HARQ process number” 4 bit long DCI field is maintained for both alternatives but with a definition extended to support 14 HARQ processes.** |
| **Qualcomm Incorporated [5]** | **Proposal 5: Introduce the following specification changes for supporting 14 HARQ processes:*** **When 14 HARQ processes are enabled, the “HARQ process number” field in DCI format 6-1A is 4 bits.**
 |

**Potential Agreement#6:**

**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).**

Companies are kindly requested to provide their views below:

|  |  |  |
| --- | --- | --- |
| **Company** | OK with Potential Agreement? | **Comments**  |
| Nokia, NSB | OK |  |
| Lenovo,MotoM | OK but no specification change? |  |
| Ericsson | OK | To Lenovo, in our understanding the “HARQ-ACK process number” field encompasses 10 HARQ processes, since in Rel-17 we will have up to 14 HARQ processes, the mapping associated to this field has to be updated as to now encompass the 14 HARQ processes. |
| Huawei, HiSilicon | OK |  |
| ZTE, Sanechips | OK |  |
| Qualcomm | OK |  |

# 5 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. [R1-2106559](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106559.zip), “Support of 14-HARQ processes in DL for HD-FDD MTC UEs,” Huawei, HiSilicon, RAN1 #105-e, May 10th – 27th, 2021.
3. [R1-2106661](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106661.zip), “Support of 14-HARQ processes in DL for eMTC,” Nokia, Nokia Shanghai Bell, RAN1 #105-e, May 10th – 27th, 2021.
4. [R1-2106848](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106848.zip), “Remaining issues on 14-HARQ processes in DL for eMTC,” ZTE, RAN1 #105-e, May 10th – 27th, 2021.
5. [R1-2106759](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106759.zip), “Support of 14 HARQ processes and scheduling delay,” Qualcomm Incorporated, RAN1 #105-e, May 10th – 27th, 2021.
6. [R1-2108117](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108117.zip), “Support of 14 HARQ processes in DL in LTE-MTC,” Ericsson, Verizon, Telefónica, SoftBank, Telstra, RAN1 #105-e, May 10th – 27th, 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.

# 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