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:

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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], 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-2e

Background: In RAN1 #105-e, it was left under Working Assumption (WA) whether to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” into a single DCI field, the WA assumes that “The field is 5 bits if Alt-2e is configured” [11]:

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| **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}. |

On whether to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-2e is configured, companies made the following observations and proposals [2-6]:

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| **Company** | **Compendium of views on whether to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-2e is configured [2-6].** |
| **Huawei, HiSilicon [2]** | **Proposal 2: If Alt-2e is configured,**   * **The PDSCH scheduling delay and HARQ-ACK delay are separately encoded in a DCI field as legacy.** |
| **Nokia, Nokia Shanghai Bell [3]** | **Proposal 3: When Alt.2e is configured, the set of HARQ-ACK delay values is {4,5,6,7,9,11,13,15}.**  ***“***   |  |  |  | | --- | --- | --- | |  | **Existing DCI** | **Alt. 2e DCI changes** | | HARQ-ACK delay | 3 | 3 | | 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.***   * ***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.*** |
| **Qualcomm Incorporated [5]** | **Proposal 2: When Alt-2e is configured:**   * **The DCI includes the following index:** * **indicates the PDSCH scheduling delay among the following:**   + **0: 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe.**   + **1 : 1 subframe + 3 BL/CE UL subframes+ 1 subframe + 2 BL/CE DL subframes.**   + **2: 2 BL/CE DL subframes.** * **, with the mapping from indices to HARQ-ACK delay values as in Table 1.** * **The combination of and is disallowed** |
| **Ericsson [6]** | **Proposal 3 The PDSCH scheduling delay and HARQ-ACK delay using Alt-2e are jointly encoded in a single DCI field consisting of 5-bits, being the 5-bits re-purposed from the “3-bits: HARQ-ACK delay” and “2-bits: Repetition number” fields.** |

Based on what was described in [2-6], the Feature Lead (FL) provides below a one-on-one comparison of the proposed solutions.

**Table 1**: **Indication of the “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt2-e is configured as in [2-6].**

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| **General Description** | **Independent indication using two DCI fields**  The “PDSCH Scheduling delay” and the “HARQ-ACK delay” are indicated using two DCI fields. | | **Joint Encoding into a single DCI field**  The “PDSCH Scheduling delay” and the “HARQ-ACK delay” are jointly encoding into a single DCI field. | | |
| **Independent Indication as in [2]:**  PDSCH Scheduling delay field: 2-bits (3 PDSCH Scheduling delay expressions)  HARQ-ACK delay field: 3-bits (8 values in the HARQ-ACK delay set)  Total Number of bits: 5-bits | **Independent Indication as in [3]:**  PDSCH Scheduling delay field: 2-bits (3 PDSCH Scheduling delay expressions)  HARQ-ACK delay field: 3-bits (8 values in the HARQ-ACK delay set)  Total 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 available  Total 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-Delay  IDCI spans from 0, 1, 2, … till 31.  10+11+11 = 32 states utilized out of 32 states available  Total Number of bits: 5-bits | **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 available  Total Number of bits: 5-bits |
| **Pros** | * Keeps independent the “HARQ-ACK delay” field as in legacy. | | * The joint encoding solutions aim at exploiting the most of the 5-bits required to indicate the “PDSCH Scheduling delay” and “HARQ-ACK delay”.   + That is, with the same 5-bits a joint encoding solution makes possible to increase the size of the HARQ-ACK delay set beyond 8 delay values. * Using a joint encoding solution to indicate the “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt-2e is configured will allow to handle ideal scenarios and non-ideal scenarios with low or moderate presence of invalid subframes, since regardless of whether the values in the HARQ-ACK delay are based on range1 or range2 the joint encoding solution increases the size of the HARQ-ACK delay set which allows to incorporate extra values. | | |
| **Cons** | * Even though the “HARQ-ACK delay” field is kept independent as in legacy, the solution anyway requires creating a “PDSCH Scheduling delay” field non-existent in legacy. * The HARQ-ACK delay set can at most contain 8 values. * Depending on the decision about the 8 values to be included in the HARQ-ACK delay set, the solution may be limited to handle only ideal scenarios. | | * In [2] it was mentioned “*the decoding complexity for the jointly encoding is higher than the separately encoding*”, nonetheless the complexity depends on the implementation in the specs of the joint encoding *per se* (e.g., table, or Index-based equation [5]), whereas decoding-wise DCI Format 6-1 already contains DCI fields consisting of many more bits. | | |

According with [2-6], when Alt-2e is configured two companies (i.e., [2] and [3]) prefer to use two separate DCI fields for the “PDSCH Scheduling delay” and “HARQ-ACK delay”, whereas three companies (i.e., [4] – [6]) prefer to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” into a single DCI field.

**Potential Agreement#1:**

**Confirm the Working Assumption for Alt-2e:**

**Working Assumption**

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 re-purposed for the jointly encoded solution of Alt-1 and Alt-2e respectively.

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| **Company** | **The** **“PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt2-e is configured are:**  **Opt-1: Jointly-Encoded in a single DCI field (i.e., Confirm the WA)**  **or**  **Opt-2: Indicated using indepedent DCI fields** | **Comments** |
| Nokia, NSB | Opt-2 | Since the total number of bits required is the same with joint encoding, we prefer to retain separate DCI fields, as we see that as begin easier to specify, develop and test. |
| FUTUREWEI | Opt-2 | Overall we have some concern on over-optimization of the 14 HARQ processes feature.  Alt 2e is agreed to be based on “3 bits (same as legacy)”. Joint coding was FFS and part of the working assumption, but we prefer separate coding as in the agreement. It is easier to specify, there would be just a new 2-bit field for the PDSCH schedling delay.  A general comment, the term „re-purpose“ is unclear. It is better to directly say that some legacy fields are set to zero bits in order to limit the potential size increase of the DCI for newly added fields. |
| Lenovo, MotoM | Opt-1 | We prefer joint coding for the PDSCH scheduling delay and HARQ-ACK delay  For Opt 2, If we use 2 bit for PDSCH scheduling delay {2, 7, 7} and 3 bit for HARQ-ACK delay  How can we specify the HARQ-ACK delay set. As we know, the HARQ-ACK delay is largely related to the PDSCH scheduling delay. There are only a few potential overlapped HARQ-ACK delay values for PDSCH scheduling delay of 2 and 7.  We prefer the joint coding similar as  If PDSCH scheduling delay=2, legacy HARQ ACK delay set {4,5,6,…11}  Otherwise, new HARQ ACK delay set {……19,20} |
| Ericsson | Opt-1 | With the same 5-bits, Opt-1 allows increasing the size of the HARQ-ACK delay set beyond 8 delay values, whereas with Opt-2 the size of the HARQ-ACK delay set will be limited to at most 8 delay values. Thus, Opt-1 brings an extra benefit (without any overhead cost) to Alt-2.  To Futurewei, about the comment “Alt 2e is agreed to be based on “3 bits (same as legacy)”, there is a difference between saying “will be based” and “will be”. For example, the values in the HARQ-ACK delay set will be based on range 1 or range 2, if we agree on a set larger than 8 values, still the set can be based on range 1 or range 2 plus extra values.  Moreover, if Alt-2e were to use indenpendent DCI fields, the HARQ-ACK delay can not be the same as legacy since at least a delay of 13 subframes would be needed. Thus, if the HARQ-ACK delay set is meant to be based on range 1 or range 2 at least one of its values would have to be left aside to make room to the value of 13 (there is little margin of maneuver if we are limited to 8 delay values, when for no cost in terms of overhead we can a couple of more values in the set). |
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The second step for Alt-2e will consist in selecting one of the solutions under the umbrella of either “Joint Encoding” or “Independent DCI fields” once it has been decided whether or not to confirm the WA when Alt-2e is configured.

Thereafter, a third step will consist in picking up the actual delay values composing the HARQ-ACK delay set(s).

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

Background: In RAN1 #105-e, it was left under Working Assumption (WA) whether to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” into a single DCI field, the WA assumes that “The field uses no more than 7 bits if Alt-1 is configured” [11]:

|  |
| --- |
| **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}. |

On the jointly encoding of the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-1 is configured, companies made the following observations and proposals [2-6]:

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| **Company** | **Compendium of views on whether to jointly encode the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-1 is configured [2-6].** |
| **Huawei, HiSilicon [2]** | **Proposal 1: If Alt-1 is configured,**   * **The PDSCH scheduling delay and HARQ-ACK delay are jointly encoded in a DCI field.** * **The field uses no more than 7 bits.** |
| **Nokia, Nokia Shanghai Bell [3]** | **Proposal 1: When Alt-1 is configured, the full set of permutations of the PDSCH scheduling delay and HARQ-ACK delay are jointly encoded using a 7-bit long DCI field.**  ***“***   |  |  |  | | --- | --- | --- | |  | **Existing DCI** | **Alt. 1 DCI changes** | | HARQ-ACK delay | 3 | 7 | | New PDSCH Delay | 0 |   ***”*** |
| **ZTE [4]** | ***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 3: When Alt-1 is configured:**   * **The DCI includes the following index:** * **indicates the PDSCH scheduling delay among the following:**   + **0: 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe.**   + **1 : 1 subframe + 3 BL/CE UL subframes+ 1 subframe + 2 BL/CE DL subframes.**   + **2: 2 BL/CE DL subframes.** * **,** |
| **Ericsson [6]** | Proposal 2: The PDSCH scheduling delay and HARQ-ACK delay using Alt-1 are jointly encoded in a single DCI field consisting of a number of bits given by Alt-1 or Alt-2 once a down-selection will be performed:   * Alt-1: 7-bits for a fully-flexible jointly encoding solution, being 5-bits re-purposed from the “3-bits: HARQ-ACK delay” and “2-bits: Repetition number” fields along with the DCI size increased by 2-bits. * Alt-2: 6-bits for a pseudo-flexible jointly encoding solution, being 5-bits re-purposed from the “3-bits: HARQ-ACK delay” and “2-bits: Repetition number” fields along with the DCI size increased by 1-bit. |

### 2.2.1 Step-1: “PDSCH scheduling delay” and “HARQ-ACK delay” using Alt-1

Based on what was described in [2-6], companies have a unified view on jointly encoding the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-1 is configured. Thus, as a first step it seems that we can confirm the WA for Alt-1.

**Potential Agreement#2:**

**Confirm the Working Assumption for Alt-1:**

**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.
* 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}.

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| **Company** | **The “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt1 is configured are Jointly-Encoded in a single DCI field (i.e., Confirm the WA)**  **OK?** | **Comments** |
| Nokia, NSB | OK to confirm WA |  |
| FUTUREWEI | Not OK to confirm the WA | The term „repurpose“ should not be used, instead directly state that some legacy fields might be set to zero bits.  Here we would also have a preference for separate coding even though it is 8 bits for full flexibility. OK however to confirm 7 bits total for these fields for Alt-1 if everyone wants to go that way, but until an exact joint coding approach is defined we prefer to keep joint coding as a working assumption and keep separate coding on the table (i.e., using 5 bits to select 32 of the 36 possibilities + 2-bit field for the PDSCH schedling delay). |
| Lenovo, MotoM | OK to confirm WA | We share the similar view as FUTUREWEI as the repurpose DCI field comments.  There is no DCI field repurpose issue at all. If the UE is configured with 14HARQ process, the repetition number field (just example) is not present, and new field will be added in DCI format 6-1A and the total DCI size can be the same as legacy. |
| Ericsson | Ok with confirming the WA | None |
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### 2.2.2 Step-2: “PDSCH scheduling delay” and “HARQ-ACK delay” using Alt-1

As a second step (i.e., if the WA for Alt-1 becomes 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 2**: **Indication of the “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt1-e is configured as in [2-6].**

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| **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 available  Total 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 available  Total 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 available  Total 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-Delay  IDCI spans from 0, 1, 2, … till 107.  36+36+36 = 108 states utilized out of 128 states available  Total 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 available  Total 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 available  Total 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. |

According with [2-6], when Alt-1 is configured two companies proposed joint encoding designs using 5-bits [4] and 6-bits [6] respectively, whereas four companies (i.e., [2], [3], [5], [6]) proposed to use joint encoding designs using 7-bits for the “PDSCH scheduling delay” and “HARQ-ACK delay” when Alt-1 is configured.

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| **Company** | **The “PDSCH Scheduling delay” and “HARQ-ACK delay” when Alt1 is configured are:**  **Opt-1: Jointly-Encoded in a single 7-bits DCI field**  **or**  **Opt-2: Jointly-Encoded in a single 6-bits DCI field**  **Or**  **Opt-3: Jointly-Encoded in a single 5-bits DCI field** | **Comments** |
| Nokia, NSB | Opt-1 | Support Alt-1 with full flexibility. If DCI size is an issue, we have Alt-2e. |
| FUTUREWEI |  | As commented above, we have a preference for separate coding. However we are OK to discuss joint coding options for alt 1 as part of the working assumption for joint coding. |
| Lenovo,MotoM | Opt-1 | We slightly prefer Opt-1. |
| Ericsson | Either Opt-1 or Opt-2 | If the 7-bit DCI overhead is not seen as an issue (which also depends on how many existing DCI bits we can re-utilize), then Opt-1 is fine, otherwise we can consider Opt-2. |
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The third step for Alt-1 will consist in selecting one of the solutions under the umbrella of either the “7-bits Joint Encoding solution” or “the less than 7-bis Joint Encoding solution”.

## 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].

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| **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” field  2-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)  Or  Option 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. |
|  |  |  |

### 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. |
| 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. |
|  |  |  |

### 2.3.1 “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” field  2-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)  Or  Option 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. |
|  |  |  |
|  |  |  |

## 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 |
|  |  |  |
|  |  |  |
|  |  |  |

### 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. |
|  |  |  |
|  |  |  |
|  |  |  |

# 5 References

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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