3GPP TSG-RAN WG1 Meeting #104-e R1-xxxxxxx

e-Meeting, January 25th – February 5th, 2021

Agenda Item: 8.9.2

Source: Moderator (Ericsson)

Title: Feature Lead Summary on [104-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) continues from what was discussed and agreed until now in RAN1 #104-e, prioritizing the down-selection of the PDSCH scheduling delay solution since the decisions on other topics highly depend on its frameworks.

Annex 1 contains the agreements reached in RAN1 #102-e [8], RAN1 #103-e [9] and the agreement reached until now in RAN1# 104-e.

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

## 2.1 Behaviour when PUCCH uses 1 repetition

Background: During the second GTW session of RAN1 #104-e the following agreement was reached:

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| **Agreement**   1. 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. |

**Comment from the Feature Lead:** The agreement above contains one term surrounded by brackets (i.e., [3 subframes]), which can be resolved from deciding whether in presence of an invalid UL subframe PUCCH using 1 repetition is postponed or not.

During the third GTW session the following options were discussed:

**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):**

* **Option 1: The presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) does not cause a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 subframes.**
* **Option 2: The presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) causes a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 BL/CE UL subframes.**

Let me try to illustrate the difference between Option 1 and Option 2, below we compare the behaviour of Option 1 and Option 2 assuming the scenario we have been discussing, this time including the periodic presence of 1 non-BL/CE UL subframe.

**Option 1: The presence of an invalid UL subframe does not cause a postponement of PUCCH**

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| Non-BL/CE UL subframes are illustrated using “0”. | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Non-BL/CE DL subframes are illustrated using “0”. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| subframe No | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| MPDCCH | 0 | 1 | 2 | 3 | 4 | 5 | 6 |  |  | 7 | 8 | 9 | 10 | 11 |  |  |  |  |  | 0 | 1 | 2 |
| PDSCH | 12 | 13 | 0 | 1 | 2 | 3 | 4 |  |  | 5 | 6 | 7 | 8 | 9 |  |  |  |  |  | 10 | 11 | 0 |
| ACK/NACK (Bundling)  0: (12, 13, 0, 1)  1: (2, 3, 4, 5)  2: (6, 7, 8, 9) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |  |

Let’s focus on HARQ-Process # 10 in subframe No 12, if as per Option 1 we count the delay of 7 using 1 BL/CE DL subframe + 1 subframe + 3 subframes + 1 subframe + 1 BL/CE DL subframe, then we will include subframe No 13, 14, 15, 16, 17, 18 and 19 as to have the PDSCH corresponding to HARQ process #10 scheduled on subframe No 19. This way of counting prevents having to waste subframes unnecessarily and avoids an unnecessary extra drop in the peak data rate. In this scenario a peak data rate of 631.5 Kbps is achieved. The required HARQ-ACK delay is impacted only by the presence of non-BL/CE DL subframes.

**Option 2: The presence of an invalid UL subframe causes a postponement of PUCCH**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Non-BL/CE UL subframes are illustrated using “0”. | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Non-BL/CE DL subframes are illustrated using “0”. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| subframe No | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| MPDCCH | 0 | 1 | 2 | 3 | 4 | 5 | 6 |  |  | 7 | 8 | 9 | 10 | 11 |  |  |  |  |  |  | 0 | 1 |
| PDSCH | 12 | 13 | 0 | 1 | 2 | 3 | 4 |  |  | 5 | 6 | 7 | 8 | 9 |  |  |  |  |  |  | 10 | 1 |
| ACK/NACK (Bundling)  0: (12, 13, 0, 1)  1: (2, 3, 4, 5)  2: (6, 7, 8, 9) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |

Let’s also focus on HARQ-Process # 10 in subframe No 12, if as per Option 2 we count the delay of 7 using 1 BL/CE DL subframe + 1 subframe + 3 BL/CE UL subframes + 1 subframe + 1 BL/CE DL subframe, then we will include subframe No 13, 14, 16, 17, 18, 19 and 20 as to have the PDSCH corresponding to HARQ process #10 scheduled on subframe No 20. This way of counting results in a peak data rate of 600 Kbps is achieved due to the postponement. The required HARQ-ACK delay is impacted by the presence of both non-BL/CE DL subframes and non-BL/CE UL subframes.

Please provide your views on the potential agreement below.

**Potential 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):**

* **Option 1: The presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) does not cause a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 subframes.**
* **Option 2: The presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) causes a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 BL/CE UL subframes.**

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| **Company** | **Option 1 or Option 2?** | **Comments** |
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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. [R1-2100254](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100254.zip), “Support of 14-HARQ processes in DL for HD-FDD MTC UEs,” Huawei, HiSilicon, RAN1 #104-e, January 25th – February 5th, 2021.
3. [R1-2100508](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100508.zip), “Support of 14-HARQ processes in DL for eMTC,” Nokia, Nokia Shanghai Bell, RAN1 #104-e, January 25th – February 5th, 2021.
4. [R1-2100568](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100568.zip), “Support additional PDSCH scheduling delay for introduction of 14-HARQ processes in DL for eMTC,” ZTE, RAN1 #104-e, January 25th – February 5th, 2021.
5. [R1-2101325](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101325.zip), “Design considerations to support 14-HARQ Feature for LTE-M,” Sierra Wireless, S.A., RAN1 #104-e, January 25th – February 5th, 2021.
6. [R1-2101510](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101510.zip), “Support of 14 HARQ processes and scheduling delay,” Qualcomm Incorporated, RAN1 #104-e, January 25th – February 5th, 2021.
7. [R1-2101699](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101699.zip), “Support of 14 HARQ processes in DL in LTE-MTC,” Ericsson, AT&T, SoftBank, Telefónica, Verizon, RAN1 #104-e, January 25th – February 5th, 2021.
8. 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.
9. 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.

# 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 (Ongoing):

Agreement

The PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1) will be selected from one of the following solutions:

Solution 1: The PDSCH scheduling delays are:

* + - 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.

Solution 2: The PDSCH scheduling delays are:

* Alt1: *x* subframes/Alt2: *x* BL/CE DL subframes

where, *x* = is signalled (FFS: signalling details) and refers to one integer value among different integer values in a given set (FFS: The values and length of the set).

Solution 3: The PDSCH scheduling delays are:

* 2 BL/CE DL subframes.
* 7 BL/CE DL subframes – *k* BL/CE DL subframes.

where, *k* = is signalled (FFS: signalling details), depends on the DL bitmap and refers to one integer value among different integer values in a given set (FFS: The values and length of the set).

**Agreement**

1. 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.

# Annex 2

## A2.1 Collected views on the down-selection of the PDSCH scheduling delay solution:

**Potential Agreement 1:**

**For the support of 14 HARQ processes, the PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1) is determined according with Solution [].**

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| **Company** | **Solution []?** | **Comments** |
| Lenovo,MotoM | Solution 2: Alt 2  Solution 3(?) | The solutions seems more clear now.  For solution 1, as moderator mentioned, save the DCI size but only handle limited/ideal scenarios.  For solution 2 (Alt 2) and solution 3, they are very similar. If solution 3 can directly use K BL/CE DL subframes, it can be our preference.  e.g., eNB RRC-configure one of the delay set from {set 1:{2 6 7 8}, set 2{2 5 7 9}, set 3(2, x,x,x)....... } based on the DL-UL valid subframe configuration, DCI use 2 bit to select one of the scheduling delay. We need to cover the most scenarios not all cases, so 2-bit scheduing delay field in DCI is enough. |
| ZTE |  | Regarding the scenarios, we are wondering why need to consider scenario 2 which is with high percentage of presence of non-BL/CE subframes and measurement gap. As evaluated in our contribution, when the percentage of presence of non-BL/CE subframes is larger than 20%, the peak data rate of 14 HARQ processes would be less than the maximum peak data rate of 10 HARQ processes. In such scenario, there is no need to enable 14-HARQ processes feature. In addition, in legacy MTC system, measurement gap is not counted in PDSCH scheduling delay. The legacy UE can drop receiving or drop transmitting if the subframes is invalid due to behavior in measurement gap.  Before we compare difference solutions, we should have common understanding on the scenarios that 14-HARQ processes would apply for. |
| Nokia, NSB |  | Solution 1 is our current preference without group clarification of scenarios we are trying to cover.  Similar to ZTE, we’d like clearer definition/agreement of the use-cases/scenarios we are designing for.  In our view, the scope of this originally simple feature has expanded almost every meeting.   * First invalid SFs (even then there was debate on %) * Now additional measurement gaps   Our fear is that we are over-engineering this feature for:   * corner scenarios * scenarios where alternative schemes will out-perform it, how would the 10-HARQ handle these scenarios (is it obvious a solution 3/2 version of 14-HARQ will outperform 10-HARQ?) * scenarios where there are no strong expectations of high data rates (e.g. lots of MBMS)   We currently lean towards solution 1. However , if the majority of the group decides these use-cases are worth handling , then we would probably favour solution 3. |
| Ericsson | See comment: Solution 1 or Solution 3 | Based on the analysis in Table 1, we prefer Solution 1 if the PDSCH scheduling delay solution is intended to only handle the presence of non-BL/CE DL subframes and non-BL/CE UL subframes, otherwise (i.e., if additional scenarios are intended tobe handled) we prefer Solution 3.  . |
| ZTE | Solution 1 | We think PDSCH scheduling delay solution only needs to handle the presence of non-BL/CE DL subframes and non-BL/CE UL subframes with percentage less than 20%. There is no need to apply 14-HARQ processes feature in some corner scenarios. |
| Ericsson (v013) | To ZTE | The percentage you are using as a reference doesn’t seem to be correct, since your argument behind it is “As evaluated in our contribution, when the percentage of presence of non-BL/CE subframes is larger than 20%, the peak data rate of 14 HARQ processes would be less than the maximum peak data rate of 10 HARQ processes”. As I explained, the problem with your statement is that you cannot compare the achievable peak rate of an ideal scenario vs a non-ideal scenario. You have to compare 10-HARQ process in a non-ideal scenario vs 14-HARQ processes in a non-ideal scenario since the 10 HARQ processes will also suffer a peak data rate loss, meaning that the 588kbps you used as reference won’t be achievable but rather 476 kbps. For the same scenario, the 14 HARQ processes will achieve 571 Kbps.  Scenario 2 is not a corner case scenario (it is rather conservative since MGL = 6), the presence of measurement gaps is not uncommon in real networks, that is why is worth considering having a solution that can handle those scenarios. The key thing here is that we also need to balance the complexity of the solution, DCI impact, signaling, etc as to take a decision. As I mentioned, from our view Solution 1 or 3 seem to be the most suitable solutions depending on the scenarios that are intended to be covered. |
| Qualcomm | Solution 2 / 3 | It is a bit unclear what is the fundamental diffrence between solution and solution 3. The only difference seems to be how to express the number of subframes (whether a delay of X or a delay of 7-X, they are equivalent), and whether the delays are configurable or not. We would be OK with any solution in which the delay is indicated in DCI (with potentially a set of values configured by RRC). |
| Huawei, HiSilicon | Solution 2 Alt 2 | We support Solution 2 Alt 2, as it covers more scenarios. Compared with Alt 1 and Solutin 3, it’s more straightforward, as the PDSCH is always transmitted in the BL/CE DL subframes.  The current Solution 1 only requires 1 bit for indication, however, in some scenarios (high reservation percentage), Solution 1 cannot fully use the available downlink subframes, e.g. the BL/CE downlink subframes between the uplink subframes transtting PUCCH. And to support such scenarios, Solution 1 will require more indicating bits.  One comment regarding Solution 3, it seems the example given below is essential the same as Solution 2 Alt 2, with the set of scheduling delay configured as {2, 3, 4, 5, 6, 7, 8, 9, 10} BL/CE DL subframes. Not quite follow the point that only 1 or 2 bits is enough for the indication.   * *2* BL/CE DL subframes * *7* BL/CE DL subframes - *k* BL/CE DL subframes, where, *k* = e.g., {-3, -2, -1, 0, 1, 2, 3, 4}. |
| FL (v016) | To Huawei | The difference is in the length of the set, Solution 2 Alt 2 requires the set you wrote (i.e., {2, 3, 4, 5, 6, 7, 8, 9, 10}) to handle Scenario 2, whereas Solution 3 requires the following set {-3, -2, -1, 0, 1, 2, 3, 4} to handle Scenario 2. As you can see, the set of Solution 2 Alt-2 is composed by 9 delays meaning you need 4-bits for it, whereas the set used by Solution 3 is composed of 8 delays meaning it requires 3-bits, that is the difference.  That is why in the FLS it was written “Solution 2 Alt2 and Solution 3 are similar, but it seems that because of the use of RRC signaling Solution 3 will require less bits in DCI than Solution 2 Alt2.” |

## A2.1 Background and updated potential agreement on the down-selection of the PDSCH scheduling delay solution:

Background: In RAN1 #104-e the following agreement was reached:

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| Agreement  The PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1) will be selected from one of the following solutions:  Solution 1: The PDSCH scheduling delays are:   * + - 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.   Solution 2: The PDSCH scheduling delays are:   * Alt1: *x* subframes/Alt2: *x* BL/CE DL subframes   where, *x* = is signalled (FFS: signalling details) and refers to one integer value among different integer values in a given set (FFS: The values and length of the set).  Solution 3: The PDSCH scheduling delays are:   * 2 BL/CE DL subframes. * 7 BL/CE DL subframes – *k* BL/CE DL subframes.   where, *k* = is signalled (FFS: signalling details), depends on the DL bitmap and refers to one integer value among different integer values in a given set (FFS: The values and length of the set). |

Below it is compared how Solution 1, Solution 2 (Alt1 and Alt2), and Solution 3 handle respectively the scenario discussed in RAN1#103-e having only presence of non-BL/CE DL subframes (i.e., invalid subframes), and one other scenario depicted in [7] which has the presence of non-BL/CE DL subframes, non-BL/CE UL subframes and Measurement Gaps.

* **Scenario 1: Presence of non-BL/CE DL subframes (i.e., invalid subframes)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Non-BL/CE DL subframes are illustrated using “0”. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| subframe No | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| MPDCCH | 0 | 1 | 2 | 3 | 4 | 5 | 6 |  |  | 7 | 8 | 9 | 10 | 11 |  |  |  |  |  | 0 | 1 | 2 |
| PDSCH | 12 | 13 | 0 | 1 | 2 | 3 | 4 |  |  | 5 | 6 | 7 | 8 | 9 |  |  |  |  |  | 10 | 11 | 0 |
| ACK/NACK (Bundling)  0: (12, 13, 0, 1)  1: (2, 3, 4, 5)  2: (6, 7, 8, 9) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |  |

* **Scenario 2: Presence of non-BL/CE DL subframes, non-BL/CE UL subframes and Measurement Gaps**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MGL |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Non-BL/CE UL subframes are illustrated using “0”. | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| Non-BL/CE DL subframes are illustrated using “0”. | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| subframe No | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| MPDCCH | 0 | 1 | 2 |  |  | 3 | 4 | 5 | 6 |  | 7 | 8 | 9 |  |  | 10 |
| PDSCH |  |  | 0 |  |  | 1 | 2 | 3 | 4 |  | 5 | 6 | 7 |  |  | 8 |
| ACK/NACK |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

The time progression of the diagram continues below

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MGL | MGL+1 subframes with no UL transmission | | | | | | |  |  |  |  |  |  |  |  |
|  | Measurement Gap Length | | | | | |  |  |  |  |  |  |  |  |  |
| Non-BL/CE UL subframes are illustrated using “0”. | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| Non-BL/CE DL subframes are illustrated using “0”. | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| subframe No | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| MPDCCH |  |  |  |  |  |  | 11 |  |  |  |  |  | 0 |  | 1 |
| PDSCH |  |  |  |  |  |  | 9 |  |  |  |  |  | 10 |  | 11 |
| ACK/NACK |  |  |  |  |  |  |  |  | 0 | 1 | 2 |  |  |  |  |

Comparison of the PDSCH Scheduling delay solutions, when PUCCH uses 1 repetition and the presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) does not cause a postponement:

**Table 1: Comparison of the PDSCH Scheduling delay solutions**

|  |  |
| --- | --- |
|  | Solution 1 |
| General description | The PDSCH scheduling delays are:   * + - 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. |
| Comparison | As in RAN1#103-e, for illustration purposes we will focus on HARQ-Process # 10 which is in subframe No 12 for Scenario 1, and in subframe No 15 for Scenario 2. |
| * Scenario 1: As illustrated in RAN1 #103-e, focusing on HARQ-Process # 10, if we count the delay of 7 using 1 BL/CE DL subframe + 1 subframe + 3 subframes + 1 subframe + 1 BL/CE DL subframe, this take us to have the PDSCH corresponding to HARQ process #10 scheduled on subframe No 19. Please note, that due that Scenario 1 does not have presence of non-BL/CE UL subframes (i.e., invalid UL subframes), on the terms surrounded by brackets we could have used either “3 subframes” or “3 BL/CE UL subframes”. * Scenario 2: Solution 1 cannot handle this scenario because none of its equations used to describe the delay of 7 match what is required by Scenario 2. |
| Number of bits that are foreseen to be required to indicate the PDSCH scheduling delay | * DCI bits: 2-bits   For example:  PDSCH scheduling delay:  00 → 2 BL/CE DL subframes.  01 → 1 BL/CE DL subframe + 1 subframe + 3 [BL/CE UL subframes] + 1 subframe + 1 BL/CE DL subframe.  10 → 1 subframe + 3 [BL/CE UL subframes] + 1 subframe + 2 BL/CE DL subframes.  11 → Not used/Reserved.   * RRC bits: None   Note: Solution 1 can handle the presence of non-BL/CE DL subframes, and the presence of non-BL/CE UL subframes applying on the terms surrounded by brackets either “3 subframes” or “3 BL/CE UL subframes” depending on whether the no postponement rule when PUCCH uses 1 repetition is followed or not.  **Total:**  2-bits in DCI  None in RRC |

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|  | Solution 2: Alt1 | Solution 2: Alt2 | Solution 3 |
| Assuming all three solutions use a 3-bit set from which the configurable variable takes its value. | | |
| General description | The PDSCH scheduling delays are:   * *x* subframes   where, *x* = e.g., {2, 3, 4, 5, 6, 7, 8, 9}. | The PDSCH scheduling delays are:   * *x* BL/CE DL subframes   where, *x* = e.g., {2, 3, 4, 5, 6, 7, 8, 9}. | The PDSCH scheduling delays are:   * *2* BL/CE DL subframes * *7* BL/CE DL subframes - *k* BL/CE DL subframes   where, *k* = e.g., {-3, -2, -1, 0, 1, 2, 3, 4}. |
| Comparison | As in RAN1#103-e, for illustration purposes we will focus on HARQ-Process # 10 which is in subframe No 12 for Scenario 1, and in subframe No 15 for Scenario 2. | | |
| * Scenario 1: Requires a PDSCH scheduling delay of 7 subframes as to avoid an unnecessary waste of subframes (NOTE: If the PDSCH scheduling delay is given in terms of absolute subframes longer delays are needed), Solution 2 Alt1 can handle it with *x* = 7 as to directly signal 7 subframes. * Scenario 2: Requires a PDSCH scheduling delay of 13 subframes as to avoid an unnecessary waste of subframes (NOTE: If the PDSCH scheduling delay is given in terms of absolute subframes longer delays are needed), Solution 2 Alt-1 cannot handle Scenario 2 with a 3-bit set since the largest value that *x* can take is 9. Please note that values in the set of *x* start from 2 since this is the minimum delay that must be signaled. | * Scenario 1: Requires a PDSCH scheduling delay of 5 BL/CE DL subframes as to avoid an unnecessary waste of subframes, Solution 2 Alt2 can handle it with *x* = 5 as to directly signal 5 BL/CE DL subframes. * Scenario 2: Requires a PDSCH scheduling delay of 10 BL/CE DL subframes as to avoid an unnecessary waste of subframes, Solution 2 Alt2 cannot handle it with a 3-bit set since the largest value that *x* can take is 9. Please note that values in the set of *x* start from 2 since this is the minimum delay that must be signaled. | * Scenario 1: Requires a PDSCH scheduling delay of 5 BL/CE DL subframes as to avoid an unnecessary waste of subframes, Solution 3 can handle it with *k* = 2, since  7 BL/CE DL subframes – 2 BL/CE DL subframes = 5 BL/CE DL subframes. * Scenario 2: Requires a PDSCH scheduling delay of 10 BL/CE DL subframes as to avoid an unnecessary waste of subframes, Solution 3 can handle it with *k* = -3, since 7 BL/CE DL subframes + 3 BL/CE DL subframes = 10 BL/CE DL subframes. |
| Number of bits that are foreseen to be required to indicate the PDSCH scheduling delay | * DCI bits: 3-bits or more   For example:  PDSCH scheduling delay:  000 → 2 subframes  001 → 3 subframes  010 → 4 subframes  011 → 5 subframes  100 → 6 subframes  101 → 7 subframes  110 → 8 subframes  111 → 9 subframes  Note: The support of a large enough set of delay values makes possible to handle a number of scenarios.  Note 2: Recall that Solution 2 Alt-1 cannot handle Scenario 2 with a 3-bit set.   * RRC bits: None   **Total:**  4-bits (To handle Scenario 2) or more in DCI  None in RRC. | * DCI bits: 3-bits or more   For example:  PDSCH scheduling delay:  000 → 2 BL/CE DL subframes  001 → 3 BL/CE DL subframes  010 → 4 BL/CE DL subframes  011 → 5 BL/CE DL subframes  100 → 6 BL/CE DL subframes  101 → 7 BL/CE DL subframes  110 → 8 BL/CE DL subframes  111 → 9 BL/CE DL subframes  Note: The support of a large enough set of delay values makes possible to handle a number of scenarios.  Note 2: Recall that Solution 2 Alt-2 cannot handle Scenario 2 with a 3-bit set.   * RRC bits: None   **Total:**  4-bits (To handle Scenario 2) or more in DCI  None in RRC. | * DCI bits: 1-bit or 2-bits   1-bit example:  PDSCH scheduling delay:  0 → 2 BL/CE DL subframes.  1 → *7* BL/CE DL subframes - *k* BL/CE DL subframes  2-bits example (For saving signaling reconfiguration in the most complex scenarios which may require two values of *k*, *k1* and *k1* are obtained from the same set and re-configured when needed via RRC signaling):  PDSCH scheduling delay:  00 → 2 BL/CE DL subframes.  01 → *7* BL/CE DL subframes - *k1* BL/CE DL subframes  10 → *7* BL/CE DL subframes - *k2* BL/CE DL subframes  11 → Reserved   * RRC bits: e.g., 3-bits or more   For example:  *k* = e.g., {-3, -2, -1, 0, 1, 2, 3, 4}.  Note: The support of a large enough set of delay values makes possible to handle a number of scenarios.  Note 2: Solution 3 can handle Scenario 2 with a 3-bit set.  **Total:**  1 or 2-bits in DCI  3 or more bits in RRC. |

**Comment from the Feature Lead:** From the analysis in Table 1, the preliminary conclusion is as follows:

* If the PDSCH scheduling delay solution is intended to only handle the presence of non-BL/CE DL subframes and non-BL/CE UL subframes, then Solution 1 seems to be the best choice since it was tailored-made for it and it only requires 2-bits in DCI.
* If the PDSCH scheduling delay solution is intended to handle a number of scenarios (e.g., non-BL/CE DL subframes, non-BL/CE UL subframes and Measurement Gaps) as a function of length of the set from which the configurable variable is picked-up, then Solution 2 and Solution 3 seem to be better choices. Between Solution 2 Alt1 and Solution 2 Alt2, Alt1 will require longer delays and the length of the set will be longer than the one required for Alt2 to provide the same result, hence Solution 2 Alt2 would be preferred. Solution 2 Alt2 and Solution 3 are similar, but it seems that because of the use of RRC signaling Solution 3 will require less bits in DCI than Solution 2 Alt2.

According with the comments added to the Feature Lead Summary (See Annex 2, A2.1), the PDSCH scheduling delay solution can be selected from the scope of the 14 HARQ processes feature:

**Potential Agreement 1:**

**In Rel-17, the scope of the 14 HARQ processes feature is intended to:**

* **Option-1: Only handle the presence of non-BL/CE DL subframes and non-BL/CE UL subframes, being the PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1) determined according with Solution 1.**
* **Option-2: Handle a number of scenarios (e.g., non-BL/CE DL subframes, non-BL/CE UL subframes and Measurement Gaps) as a function of length of the set from which the configurable variable used to indicate the delay is picked-up, being the PDSCH scheduling delay for the PUCCH non-repetition case (i.e., PUCCH repetitions = 1) determined according with [Solution 2:Alt2 or Solution 3].**

## A2.1 Postponement vs no-Postponement of PUCCH when it uses 1 repetition:

Background: During the second GTW session of RAN1 #104-e the following agreement was reached:

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| **Agreement**   1. 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. |

**Comment from the Feature Lead:** The agreement above contains one term surrounded by brackets (i.e., [3 subframes]), which can be resolved from deciding whether in presence of an invalid UL subframe PUCCH using 1 repetition follows the legacy behaviour or not.

Please note that this decision is also crucial towards starting the discussion on the HARQ-ACK delay set, since in case the legacy behaviour were not followed, handling the postponement of PUCCH will cause having to include more delay values in the HARQ-ACK delay set.

**Potential Agreement 1:**

**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):**

* **Option 1: The legacy behaviour is followed, and the presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) does not cause a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 subframes.**
* **Option 2: The legacy behaviour is not followed, and the presence of a non-BL/CE UL subframe (i.e., invalid UL subframe) causes a postponement of PUCCH if it uses 1 repetition, therefore the term surrounded by brackets in Solution 1 is resolved as 3 BL/CE UL subframes.**

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| **Company** | **Option-1 or Option-2?** | **Comments** |
| ZTE | Option 2 | The non-BL/CE UL subframes may have significant interfence. If the bundled HARQ-ACKs can be transmitted in the non-BL/CE UL subframes, the perfomance cannot be guaranteed due to potential interference. Therefore, PUCCH with 1 repetition should be postponed in a non-BL/CE UL subframe. |
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