**3GPP TSG RAN WG1 Meeting #106-E R1-210xxxx**

**e-Meeting, August 16th – 27th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Summary of discussion on PDSCH processing time per Capability 2 and DCI format 1\_0**

**Agenda item: 7.1**

**Document for:** **Discussion and Decision**

# Introduction

This document summarizes the following discussion thread, relevant to Rel-15/16 NR specifications:

[106-e-NR-7.1CRs-04] Issue#6: PDSCH processing time per Capability 2 and DCI format 1\_0 by August 20 – Debdeep (Intel)

[R1-2106684](file:///C:\Users\dchatt2\OneDrive%20-%20Intel%20Corporation\Documents\work\3gpp\RAN1\Contribution%20reviews\RAN1_106e_review\allTdocs_R1-106e\R1-2106684.zip) PDSCH processing time per Capability 2 and DCI format 1\_0 Spreadtrum Communications

[R1-2107568](file:///C:\Users\dchatt2\OneDrive%20-%20Intel%20Corporation\Documents\work\3gpp\RAN1\Contribution%20reviews\RAN1_106e_review\allTdocs_R1-106e\R1-2107568.zip) On UE processing capability #2 and PDSCH scheduled by DCI 1\_0 Intel Corporation

[R1-2107677](file:///C:\Users\dchatt2\OneDrive%20-%20Intel%20Corporation\Documents\work\3gpp\RAN1\Contribution%20reviews\RAN1_106e_review\allTdocs_R1-106e\R1-2107677.zip) Processing time for PDSCH scheduled by DCI format 1\_0 Huawei, HiSilicon

[R1-2107995](file:///C:\Users\dchatt2\OneDrive%20-%20Intel%20Corporation\Documents\work\3gpp\RAN1\Contribution%20reviews\RAN1_106e_review\allTdocs_R1-106e\R1-2107995.zip) Capability 2 and fallback DCI format 1-0 PDSCH handling Ericsson

# Background and summary of submitted tdocs

During RAN1 #105-e meeting, the issue of determining minimum UE processing time for processing unicast PDSCH scheduled by DCI format 1\_0 with greater than 7 symbols or 4 symbols for PDSCH mapping types A and B respectively in a serving cell configured with Cap #2 PDSCH processing timeline was discussed, and various possible interpretations and solutions to address the shortcomings in current specifications were identified [1].

The fundamental issue at hand is that PDSCHs, scheduled by DCI format 1\_0 and of durations longer than certain thresholds, are expected to have additional DMRS symbols that the UE is expected to process (in addition to the front-loaded (FL) DMRS symbol), but this makes satisfying Cap #2 processing timeline practically infeasible for UE implementation.

Accordingly, for this scenario, the possible interpretations on PDSCH processing times and DMRS assumptions can be summarized as below [1].

|  |
| --- |
| * If *processingType2Enabled* in *PDSCH-ServingCellConfig* is configured for the cell and set to ‘enable’, and if *dmrs-AdditionalPosition = ‘pos0’* in *DMRS-DownlinkConfig* in both of *dmrs-DownlinkForPDSCH-MappingTypeA, dmrs-DownlinkForPDSCH-MappingTypeB,* then, for a PDSCH scheduled by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively, one of the following for min UE processing times and DMRS assumptions respectively apply:   + **Proc\_Time\_Alt 1:** PDSCH processing time per Cap #2 applies   + **Proc\_Time\_Alt 2**: PDSCH processing time per Cap #1 with additional DMRS applies   + **Proc\_Time\_Alt 3**: PDSCH processing time per Cap #1 without additional DMRS applies   + **Proc\_Time\_Alt 4**: UE is not expected to provide a valid HARQ feedback   + **DMRS\_Alt 1:** PDSCH DMRS as per ‘pos2’ at least for PDSCH RE mapping but UE is not expected to process additional DMRS symbols for PDSCH reception (i.e. per ‘pos0’ for channel estimation for PDSCH reception)   + **DMRS\_Alt 2:** PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception   + **DMRS\_Alt 3:** PDSCH DMRS as per ‘pos0’ for both PDSCH RE mapping and channel estimation for PDSCH reception |

The candidate conclusions/spec-updates and their implications that were identified during RAN1 #105-e are detailed in the Appendix in Table A-1 ([1]). Descriptions for the different options are listed below in Table 1 for convenience.

**Table 1. Identified Options for defining UE behavior and assumptions for the issue identified during RAN1 #105-e on PDSCH processing time per Capability 2 and DCI format 1\_0.**

|  |  |
| --- | --- |
| **Option** | **Description** |
| A | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.   + UE is not expected to provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell. |
| A1 | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., with additional DMRS per ‘pos0’ only)***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies   + UE is not expected to provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 ~~with~~ *~~l~~~~d~~ ~~> 7~~* ~~or~~ *~~l~~~~d~~ ~~> 4~~* ~~symbols for mapping types A or B respectively~~ in the cell. |
| B | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies   + UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of a unicast PDSCH actually containing additional DMRS that the UE is expected to process. |
| B1 | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 1 (PDSCH DMRS as per ‘pos2’ for PDSCH RE mapping but UE is not expected to process additional DMRS symbols for PDSCH reception) applies.   + UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of a unicast PDSCH scheduled by DCI format 1\_0 actually having additional DMRS or not.     - UE is NOT expected to process any additional DMRS.     - Existing DMRS mapping and rules are maintained. |
| B2 | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 3 (PDSCH DMRS as per ‘pos0’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies   + UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of a unicast PDSCH scheduled by DCI format 1\_0 actually having additional DMRS or not.     - UE is NOT expected to process any additional DMRS.     - DMRS mapping rule is updated – if Cap #2 is configured and additional DMRS is not configured, then UE assumes DMRS per ‘pos0’ for PDSCH scheduled by DCI 1\_0 subject to HARQ-ACK feedback. |
| C | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For a PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCH”), the UE may fall back to Cap #1 timeline; other PDSCHs are to follow Cap #2 timeline, subject to any other applicable constraints (e.g., Cap 2 with 136 PRBs constraint for 30 kHz)***   + For a unicast PDSCH scheduled by DCI 1\_0, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.   + All PDSCH durations can be scheduled by DCI format 1\_0 for unicast PDSCH. |

However, RAN1 failed to arrive at a consensus on the way forward for Rel-15 and Rel-16 and the discussion was recommended to be continued during RAN1 #106-e.

As indicated in the Introduction section, four companies shared their views in tdocs submitted to RAN1 #106-e meeting. These views are summarized below in Table 2.

**Table 2. Summary of company proposals to RAN1 #106-e to the issue identified during RAN1 #105-e on PDSCH processing time per Capability 2 and DCI format 1\_0.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Proposal for Rel-15** | **Proposal for Rel-16** | **Moderator’s comments** |
| Spreadtrum | Options A or A1 | Options A or A1 or C | * Options B1, B2 seem to have not been considered in this tdoc. * Option A1 is even more restrictive than necessary (while Option A is already seen as restrictive to some) and could even be deemed NBC (and need spec updates) since for PDSCH durations with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively, there is no issue. * ***Note:*** For Option C, some UE behavior to allow UE to drop certain PDSCH(s) to avoid overlapping processing pipelines as for the case of *pdsch-ProcessingType2-Limited* would be necessary. |
| Intel | Option A | Option B1 |  |
| HW-HiSi | ***Proposal: The solution handling the case when cap#2 is configured and a unicast PDSCH is scheduled by DCI format 1\_0 and then followed by a unicast PDSCH scheduled by DCI format 1\_1, should take both the feasibility of UE implementation and restriction of gNB scheduling into account.*** | | * Although not explicitly proposed, Options C and B1 are indicated as possibly reasonable options considering trade-off between UE implementation and gNB restrictions. * Not clear if the proposal is for both Rel-15 and Rel-16 or only for Rel-16. * ***Note:*** For Option C, some UE behavior to allow UE to drop certain PDSCH(s) to avoid overlapping processing pipelines as for the case of *pdsch-ProcessingType2-Limited* would be necessary. |
| Ericsson | Option C with scheduling restriction to avoid overlapping processing pipelines as for the case of *pdsch-ProcessingType2-Limited.* | | Not clear if the proposal is for both Rel-15 and Rel-16 or only for Rel-16. |

# Discussion

# For Rel-15

As expressed by multiple companies, it would be prudent to try to avoid spec impact to Rel-15 specifications.

Option A1 precludes any unicast PDSCH scheduled by DCI 1\_0 in a DL cell configured with Cap 2 and no additional DMRS. However, this would be excessively constraining, since, as per current specifications, for the concerned scenario, there is no issue/ambiguity for shorter unicast PDSCH durations (with *ld ≤ 7 or ld ≤ 4* for PDSCH mapping types A and B respectively) without additional DMRS symbols to follow Cap #2 timing.

As also observed in company contributions, Option B lends itself infeasible to a typical UE implementation consistent with NR designs and considerations till date.

The other identified options (Options B1, B2, and C) all would require some spec update, and thus, may not be desirable at this stage for Rel-15.

Thus, Option A could be an option to conclude on (w/o spec impact) for Rel-15. Depending on existing implementations (or the lack thereof), the scheduling restrictions from Option A can be lived with (if already implemented) or avoided (if not implemented yet).

Further, it should be noted that a RAN1 conclusion would be necessary for Rel-15 to ensure common understanding considering the clear evidence of different interpretations across companies as expressed since RAN1 #105-e meeting. Considering the above, the following is proposed for Rel-15 (note that this is essentially same as Moderator Proposal 1 from RAN1 #105-e with some editorial updates).

## Moderator Proposal 1

* ***Conclusion:*** *For Rel-15 specifications,*
  + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:*
    - ***All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)***
    - For a unicast PDSCH scheduled by DCI 1\_0, **DMRS\_Alt 2** (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.
    - UE **~~is not expected to~~ may not** provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell

*Kindly elaborate (w/ justifications) on suitable alternative(s) for Rel-15, including any option(s) not identified so far, if the above is not preferred/acceptable.*

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree? (Y/N)** | **Comments** |
| Qualcomm | No | We do not think any conclusion is necessary. Following is already clear from the spec. The proposed conclusion is not aligned with this spec language.  *Otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH.* |
| ZTE | No | The conclusion implies that the UE does not expect to be scheduled with a unicast PDSCH by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B. This would cause huge scheduling restriction, and it is NBC.  In addition, we don’t agree that Option B1, B2, and C would require spec update while not for Option A and A1. In our view, we could draw a conclusion either without any spec update or with spec update, regardless of which option is chosen.  We would be ok with Option B or Option C.  [Moderator] It would be appreciated if you could elaborate how Option B1/B2/C can be specified without any spec updates. |
| Ericsson | No | We are not OK to add such severe scheduling restriction on TDRA.  We also agree with Qualcomm that this is not consistent with existing spec “*otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH*” |
| OPPO | No | In our understanding, additional DMRS is expected by UE for DCI format 1\_0 with ld > 7 or ld > 4 symbols. In this case, for a UE configured with Cap #2, the following should be applied:  “*otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH*”  Then we think a conclusion with different wording from current spec. is not needed. |
| Moderator |  | The last sub-bullet is updated to align with spec-language (although there is no practical difference between the earlier version *“UE is not expected to provide a valid HARQ-ACK …”* and spec-language *“UE may not provide a valid HARQ-ACK …”*).  **It would help the progress if companies who still see inconsistency with current specs can spell out the normative differences.**  Next, on those indicating that the proposal is severely limiting for gNB scheduling and that no conclusion is necessary, it would be appreciated if they can indicate what is the expected gNB and UE behavior if not same as indicated in the Proposed Conclusion. Just repeating the “catch-all” statement from the spec “*Otherwise the UE may not provide a valid HARQ-ACK feedback …*” does not help align the understanding across companies if there are differences in companies’ views on what the “valid conditions” are.  **We can certainly NOT make a conclusion, but it is important that we all reach a common understanding on the Rel-15 specs.**  Specifically, please indicate if your reading of current specs implies that under the given conditions, a UE can be scheduled with unicast PDSCH with with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively and still be expected to provide valid HARQ-ACK feedback according to Cap #2 timing. If not, then please highlight the difference from the Proposed Conclusion (with the understanding that the Proposal is not a CR for the specifications). |
| HW/HiSi | Partly | As discussed in the last meeting, companies have a different understanding how the specification shall be interpreted.  We think it might not be necessary to make any conclusion at all. However, if a conclusion is desired by the group, we should not try to agree on a certain interpretation here, but instead only define a behavior that is compliant with the different interpretations discussed last meeting.  Therefore, if the group wants to make a conclusion, the first sub-bullet should be removed in our view, and only the last two sub-bullets need to be captured.   * ***Conclusion:*** *For Rel-15 specifications,*   + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:*     - ***~~All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)~~***     - For a unicast PDSCH scheduled by DCI 1\_0, **DMRS\_Alt 2** (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.     - UE **~~is not expected to~~ may not** provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell |
| Moderator |  | Please share your views on the following Updated Moderator Proposal 1 based on the suggestion from HW-HiSi: Updated Moderator Proposal 1  * ***Conclusion:*** *For Rel-15 specifications,*   + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:*     - ***~~All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)~~***     - For a unicast PDSCH scheduled by DCI 1\_0, **DMRS\_Alt 2** (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.     - UE **~~is not expected to~~ may not** provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell. |
| Samsung | No | In our understanding, Rel-15 implies that if a UE can process additional DMRS according to Cap#2 timing, the UE can be scheduled with unicast PDSCH with DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively and still be expected to provide valid HARQ-ACK feedback according to Cap #2 timing. Otherwise, the UE does not report the capability of Cap#2.  Based on our understanding, a UE configured with Cap#2 in a DL cell should provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively in the cell.  In summary, we think the spec is clear and the conclusion is not necessary.  **[Moderator2]** In Rel-15, Cap #2 was defined with explicit assumption of front-loaded DMRS only. The timelines agreed for Cap #2 make it practically infeasible to support Cap #2 for a PDSCH with additional DMRS. For this reason, Cap #2 was conditioned on “no additional DMRS” configuration by higher layers. **So, the assumption that UE should be able to turn around per Cap #2 timing for a PDSCH having additional DMRS symbols is not consistent with Rel-15 design.** |
| Qualcomm2 |  | As we commented in [105-e-NR-7.1Cs-01] at the last meeting, our proposed conclusion (if necessary) is as following.  **There is no PDSCH processing timeline requirement for a PDSCH with DMRS with ‘pos2’, including a PDSCH scheduled by a DCI format 1\_0, on a DL cell with *processingType2Enabled* set to ‘enable’.**  Alternatively, if we go with the FL proposal, in addition to the HW/HiSi’ suggestion, following change (highlighted in red) is necessary to align the spec.   * ***Conclusion:*** *For Rel-15 specifications,*   + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:*     - ***~~All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)~~***     - For a unicast PDSCH scheduled by DCI 1\_0, **DMRS\_Alt 2** (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies.     - UE **~~is not expected to~~ may not** provide valid HARQ-ACK feedback in response to a unicast PDSCH scheduled by DCI format 1\_0 ~~with~~ *~~l~~~~d~~ ~~> 7~~* ~~or~~ *~~l~~~~d~~ ~~> 4~~* ~~symbols for mapping types A or B respectively in the cell~~   **[Moderator2]** As discussed before, with the suggested change (i.e., same proposal as Option A1), the conclusion would be unnecessarily restrictive than what current specs can support since PDSCHs with short durations scheduled by DCI 1\_0 can certainly be processed within Cap #2 timeline per current specifications. |
| Ericsson2 | No | We are OK with keeping current status for Rel-15. We prefer it over the proposed conclusions under consideration. |
| Spreadtrum | Yes | We are fine with the version of Updated Moderator Proposal 1 or Qualcomm2. |
| vivo | No | It seems there are different understandings for the Rel-15 spec. We think the better way is to keep the spec of Rel-15 as it is. In other word, we don’t need to draw any conclusion for Rel-15 behavior. |
| OPPO1 |  | We are fine with the latest proposal for Huawei or QC, which is consistent with our understanding. Even without any conclusion, it would be difficult to change Rel-15 implementation at this stage though UE and network may have different understanding. |

# Observations from company inputs for Rel-15

* Some companies prefer no conclusion and consider Rel-15 specs as clear already, although it can be seen from the discussion above, that these companies have very different views on what Rel-15 specs mean to them.
* Even if we leave Rel-15 as is without any conclusion, effectively, for any practical use, the most conservative assumption would need to be applied by the gNB, which is Option A or A1: **For the scenario under discussion, UE may not provide valid HARQ-ACK feedback in response to unicast PDSCH scheduled by DCI 1\_0, *at least* for unicast PDSCH with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell**. This would be the bottom-line regardless of companies’ opinions on clarity of Rel-15 specs and accuracy of their interpretation.

Considering the above, it is recommended not to spend more time on this issue for Rel-15 and just acknowledge that different conflicting interpretations exist for Rel-15 specs.

## Proposed Conclusion 1

* *No common understanding exists in RAN1 on Rel-15 specifications for the handling of unicast PDSCH scheduled by DCI 1\_0 for a UE configured with Cap #2 and no additional DMRS by higher layers in a DL cell.*

Please indicate below *only if* you have any strong opinions to the above.

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |

# For Rel-16

For Rel-16 specifications, it would not be desirable to maintain the severe restrictions of Options A/A1, especially since Rel-16 specifications may be expected to see some of the first UEs with Cap #2 support and deployments with Cap #2 configurations in the context of URLLC/IIoT use-cases. Restricting unicast PDSCH TDRA options (especially slot-based) for when scheduled by fallback DCI format can be quite a significant restriction to gNB scheduler.

The constraint (e.g., one results from Option A), that a UE, configured with Cap #2 timing for PDSCH in a DL cell, cannot be scheduled with unicast PDSCH with with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively by fallback DCI format during the “RRC ambiguity period”. Here, it is highlighted that, for unicast PDSCH scheduling, specifying that “UE is not expected to provide valid HARQ-ACK feedback” for certain configurations is, for the most part, equivalent to a scheduling restriction (except for the corner cases wherein a HARQ-ACK feedback may not be consequential for a unicast PDSCH, e.g., at the end of the user plane (UP) delay budget for the PDSCH TB).

Thus, it would be reasonable to consider some options that can achieve a better tradeoff between UE implementation challenges and gNB scheduling restrictions and latency/reliability/throughput performance.

Towards this, as a first step, based on the prior discussions and inputs in company contributions to RAN1 #106-e, the following is proposed for Rel-16 specifications, with the aims of final down-selection in the second round of discussions based on received inputs from companies.

Option B1 allows for all unicast PDSCHs, regardless of duration, can follow Cap #2 timing in the DL cell even when scheduled by DCI 1\_0, as was originally intended. At the same time, it avoids impact to PHY channel design and PDSCH DMRS and RE mapping, as against Option B2. This is achieved by simply not expecting the UE to process the additional DMRS symbols for PDSCH demodulation when scheduled by DCI 1\_0. In light of the fact that the UE is configured with Cap #2 without additional DMRS symbols (via higher layers), the demodulation performance for PDSCH scheduled by DCI 1\_0 would be similar to DCI 1\_1 and thus, acceptable for most cases. The PDSCH reliability that may be “lost” due to not processing additional DMRS symbols can be compensated with appropriate MCS selection for the PDSCH.

On the other hand, Option C still expects the UE to process additional DMRS symbols when present in a PDSCH as per Rel-15 specifications, but is now allowed to fall back to Cap #1-based timing for the corresponding HARQ-ACK feedback.

Next, to address impact to UE pipelining architecture, the UE may be allowed to skip decoding one or more unicast PDSCH(s) scheduled by DCI 1\_0 (with additional DMRS symbols) if they are scheduled within a certain window before the start of a unicast PDSCH following Cap #2 timing (e.g., as proposed in [5]):

“… UE may skip decoding a number of PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled with DCI 1\_0 following capability 1 processing time, where N = 8 for PDSCH with 15kHZ SCS, N = 10 for PDSCH with 30kHZ SCS, N = 17 for PDSCH with 60kHZ SCS”

## Moderator Proposal 2

* *For Rel-16 specifications,*
  + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers, one of the following Options is supported:* 
    - *Option B1*
    - *Option C, with the associated UE behavior:*
      * *UE may skip decoding one or more unicast PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled with DCI 1\_0 following capability 1 processing time, where N = 8 for PDSCH with 15kHZ SCS, N = 10 for PDSCH with 30kHZ SCS, N = 17 for PDSCH with 60kHZ SCS.*
    - *Other option(s)? (please elaborate)*

*Please also indicate your preference between Options B1 and C, with justifications from your side.*

*Also, kindly elaborate (w/ justifications) on suitable alternative(s), including any option(s) not identified so far, for Rel-16 if the above is not preferred/acceptable.*

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Comments** |
| Qualcomm | Other | First of all, we should first understand that any potential solution requires a new Rel-16 capability signalling.  Option B1 requires a new way of PDSCH process; TB size determination is based on front-loaded DMRS + additional DMRS, while channel estimation/decoding are based on front-loaded DMRS only, and this is only for a unicast PDSCH scheduled by DCI format 1\_0. We think this should be avoided.  With Option C, a UE is required to cancel/drop on-going Cap1 PDSCH process when the UE starts to process Cap2 PDSCH. This is not aligned with the fundamental framework of PDSCH processing capability 2 – i.e., dynamic switch between Cap1 and Cap2 for the given DL cell has not been considered (other than the case with *pdsch-ProcessingType2-Limited*).  A possible compromise is to let UE to support Cap1 PDSCH timeline for a PDSCH with additional DMRS scheduled by a DCI format 1\_0 in a DL cell configured with Cap2, while scheduler ensures that a Cap1 PDSCH process is not interrupted by a Cap2 PDSCH process in the DL cell. This can be realized by following.   * *UE does not expect to receive one or more unicast PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled by DCI format 1\_0 following capability 1 processing time* * *N is not smaller than N1 + d1,1 where the values of N1 for SCS 15kHz, 30kHz, and 60kHz are given by the right column of Table 5.3-1 in TS38.214*   + *Exact values to be confirmed* * *For the above, new Rel-16 UE capability signalling is introduced.*   [Moderator] Option B1 is the least invasive option and the impact in terms of TBS determination and channel estimation is trivial since both components are anyway implemented and available at the UE.  Option C is exactly the same as the handling specified in Rel-15 for the case of *pdsch-ProcessingType2-Limited*, as well as in LTE sTTI, and in this regard, rather well-aligned with existing specs and the framework of min. UE processing timelines defined in Rel-15.  For the proposed alternative to Option C, the issue is that gNB scheduler is expected to predict ahead and not schedule unicast PDSCH scheduled by DCI 1\_0 with additional DMRS symbols if a unicast PDSCH to follow Cap #2 timing is forthcoming. This would not be practical for use in the context of Cap #2 use-cases that aim for low latency. This is the reason existing LTE and NR specs allows the gNB to schedule but also allows the UE to drop processing of a “slow PDSCH” in lieu of processing of a “more urgent” PDSCH that satisfies Cap #2 timeline. Thus, it would not be desirable to introduce new UE and new (more restrictive) gNB behaviors compared to an already existing solution in the specifications for a very similar issue of overlapping processing pipelines.  A separate UE capability to address the issue in Rel-16 is a reasonable suggestion to consider. |
| ZTE | Option B or Option C | Our preference is Option B, while if there are concerns about overlapping processing pipelines, Option C is also ok for us. |
| Ericsson | Option B or C or other | Our preference is Option B, but we would also be OK with Option C.  We are not OK with B1 which implies (advanced) cap2 UE is allowed to have worse performance than a baseline cap1 UE.  Regarding QC proposal, we are open to introducing a new capability for Rel-16. For the behavior of cap1 followed by cap2, our preference is to align behavior with current spec for cap2 with 136 PRB limitation (simpler for implementation). |
| OPPO | Option A/C | Our preference is option A for backward compatibility. For Rel-16, we can just have a conclusion similar to proposal 1.  We can also accept option C with additional restriction to avoid overlapping processing pipelines for cap#1 and cap#2. The proposal from QC is fine to us. |
| Moderator |  | A separate UE capability, as suggested by QC, to address the issue in Rel-16 is a reasonable suggestion to consider. Companies are requested to share their views on this, especially if there may be concerns. Certainly, the definition of UE capability would depend on the solution adopted for Rel-16. |
| Hw/HiSi | B1 | Option C with the scheduling restrictions makes the situation unnecessarily complicated. Even the performance would be degraded since the earlier PDSCH scheduled by DCI 1\_0 would be dropped in some cases.  Option B1, on the other hand, is simple and has no scheduling restrictions. Also, since this situation anyhow only occurs when a PDSCH scheduled by DCI 1\_1 is without additional DMRS, there should not be any significant impact on the performance if a PDSCH scheduled by DCI format 1\_0 is only using the first DMRS. |
| Samsung | Option B1 or Option C | Option B1 avoids impact to PHY channel design and PDSCH DMRS and RE mapping. Less complex changes are required for channel estimation and decoding.  In our view, Option B1 is preferred because of less complex changes. If Option B1 is required to be avoided due to new way of PDSCH process as Qualcomm mentioned, Option C can be a solution. |
| Qualcomm2 |  | We still support our proposal above. It is true that Option C is similar to the existing spec for *pdsch-ProcessingType2-Limited*. However, this does not mean the UE behaviors for *pdsch-ProcessingType2-Limited* are applicable to generic Cap#2 scenarios. With Option C, a UE is required to cancel/drop on-going Cap1 PDSCH process when the UE starts to process Cap2 PDSCH, which is no longer just a maintenance from our point of view.  If a network configures Cap2 for a DL cell of a UE, we do not think the network would actively switch Cap1 PDSCH and Cap2 PDSCH on the DL cell for the UE. Cap1 PDSCH is scheduled only when it is really necessary, e.g., when the network observes PDCCH detection issue, when the network wants to send HO command in robust way, etc. Therefore, the scheduling restriction that we propose above should not bring performance degradation to the system.  We agree with Ericsson that, in addition to what we wrote above, Option B1 results in worse PDSCH demodulation performance and hence the benefit of supporting this feature itself is not justifiable. We agree with FL that details of the possible UE capability signalling for this new UE behavior depends on the solution.  **[Moderator2]** Some observations below:   * The appeal of Option C is that the solution already exists in the specs for a very similar issue of overlapping processing timelines. This involves a UE behavior that is already specified, and as part of Option C, it is also expected that a capability will be associated with it, if Option C is agreed. * If UE implementation is a concern for Option C in dropping a “Cap #1 PDSCH (with additional DMRS)”, then Option B1 offers the best way out as it does not introduce any new operations that the UE already does not support. There should not be additional implementation complexity/challenges for a UE to perform channel estimation based on the FL DMRS symbols only. * For the scenario of interest, the newly proposed option (**Option C1**) is effectively very similar as Option A or A1. Cap #2 is configured in a DL cell to satisfy low latency requirements, but now if there is a PDSCH with additional DMRS (a “Cap #1 PDSCH”), then the gNB would have to delay subsequent urgent PDSCHs that likely would need to be dropped due to missed delay budgets. Thus, for any practical gNB, if it cares for low latency (which is why Cap #2 is configured in the first place), would need to avoid scheduling unicast PDSCH by DCI 1\_0, and when it does, block future PDSCH scheduling (e.g., for URLLC/IIoT traffic for the UE) with Cap #2 turn-around times. This is a serious issue that compromises the fundamental motivation of configuring Cap #2 in the cell by forcing gNB to delay/deprioritize Cap #2 PDSCH if there is any unicast PDSCH scheduled by DCI 1\_0. * Use of scheduling with “Cap #1 PDSCH” can be more than corner case as has been discussed in the past – this would be a typical candidate for use during any RRC reconfiguration event, and not limited to “deteriorating link conditions”. Thus, the impact to latency performance from Option C1 can be significant. * On performance, please see response to Ericsson2. |
| Ericsson2 |  | From our perspective, how fast a PDSCH scheduled by DCI 1\_0 can be processed is not an essential issue, it is more important that UE handles same PDSCH combinations as for cap#1 to ensure the RRC reconfiguration messages are not adversely impacted, and this includes the performance aspect.  Overall, , while option C is our first preference (to align with the current spec), we would also be OK with the scheduling restriction approach (along with Rel-16 UE capability) proposed by Qualcomm.  **[Moderator2]** On performance, the impact on demodulation performance for the PDSCHs scheduled by 1\_0 with additional DMRS (but not decoding using the additional DMRS for channel estimation) should not be the bottleneck since, for the scenario of interest, the UE is configured to operate without additional DMRS symbols for PDSCH scheduled by DCI 1\_1 or 1\_2. Thus, overall negative impact to performance for Option B1 would be negligible at worst and non-existent for most cases.  Further, from the performance perspective, it seems a bit contradictory that there are concerns on Option B1 on grounds of performance for those PDSCHs with additional DMRS, while Option C, that actually allows UE to skip decoding entirely for those PDSCHs if there may be a PDSCH with Cap #2 closely following, is acceptable. Here, it is understood that if there is no PDSCH with Cap #2 timing, the PDSCH with additional DMRS can enjoy the better channel estimation from additional DMRS, but the premise of the scenario at hand is that the UE is configured to operate with Cap #2 on the cell for latency/reliability requirements. |
| Spreadtrum | Option C or proposal from Qualcomm |  |
| vivo | Option C | Our preference is Option C.  Option C can align the behavior with current spec for Cap#2 in case of 136 PRB limitation. |

**Summary of company views:**

* A new option has been proposed during this round of discussions, **Option C1**:
  + *UE does not expect to receive one or more unicast PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled by DCI format 1\_0 following capability 1 processing time*
  + *N is not smaller than N1 + d1,1 where the values of N1 for SCS 15kHz, 30kHz, and 60kHz are given by the right column of Table 5.3-1 in TS38.214*
    - *Exact values to be confirmed*
  + Please refer to comments in response to Option C1 tagged with **[Moderator2]** in response to Qualcomm2 in the above table.
* Consideration of defining **separate UE capability** is acknowledged, at least for any option that introduces new UE behavior.

**Snapshot of current company preferences:**

* **Option A**: Oppo **(1)**
* **Option B**: ZTE **(1)**
* **Option B1**: HW-HiSi, Samsung, Intel (1st pref) **(3)**
* **Option C**: ZTE, E// (1st pref), Oppo, Samsung, SPRD, vivo, Intel (2nd pref) **(7)**
* **Option C1**: QC, E// (2nd pref), SPRD **(3)**

It cannot be stressed enough that if we cannot converge on one option, we essentially fall back to the Rel-15 situation – no common understanding across companies for Rel-16 either, effectively rendering Cap #2 feature with a severe handicap for practical URLLC/IIoT use-cases.

Considering the “popular” options further, the pros/cons are summarized below for convenience:

|  |  |  |
| --- | --- | --- |
| **Option** | **Pros** | **Cons** |
| **B1** | * No scheduling restrictions and no adverse impact to URLLC/IIoT scheduling. * Minimal impact to specs. * Minimal impact to gNB and limited impact to UE implementations. * All unicast PDSCHs can be scheduled with Cap #2 timelines, enabling better latency performance. | * Potential reduction in demodulation performance for the PDSCHs with additional DMRS if the additional DMRS symbols may not be used by UE for demodulation. * “New UE way of PDSCH processing”, although the constituent components involve operations that the UE already supports |
| **C** | * No scheduling restrictions and no adverse impact to URLLC/IIoT scheduling. * Solution is already used in current specs to address a very similar case of overlapping processing time pipelines. | * UE needs to drop a “Cap #1 PDSCH” if it receives a “Cap #2 PDSCH” within a time window following the “Cap #1 PDSCH”. |
| **C1** | * Minimal impact to UE implementation. | * Severe scheduling restrictions – once a “Cap #1 PDSCH is scheduled” the UE cannot be scheduled with an urgent “Cap #2 PDSCH” within a time window following the “Cap #1 PDSCH” * gNB expected to predict future traffic, or alternatively avoid scheduling of “Cap #1 PDSCH”, or compromise on latency performance for URLLC/IIoT scheduling. |

With this, companies are encouraged to share their views on the following proposal to try for possible convergence.

## Moderator Proposal 2a

* *For Rel-16 specifications,*
  + *For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers, one of the following Options is supported:* 
    - *Option B1*
    - *Option C, with the associated UE behavior:*
      * *UE may skip decoding one or more unicast PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled with DCI 1\_0 following capability 1 processing time, where N = 8 for PDSCH with 15kHZ SCS, N = 10 for PDSCH with 30kHZ SCS, N = 17 for PDSCH with 60kHZ SCS.*
    - *Option C1, with the associated UE behavior:*
      * *UE does not expect to receive one or more unicast PDSCHs with last symbol within N symbols before the start of a PDSCH that is scheduled to follow capability 2 processing time, if any of those PDSCHs are scheduled by DCI format 1\_0 following capability 1 processing time*
      * *N is not smaller than N1 + d1,1 where the values of N1 for SCS 15kHz, 30kHz, and 60kHz are given by the right column of Table 5.3-1 in TS38.214*
        + *Exact values to be confirmed*

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Comments** |
|  |  |  |

# Summary of discussion

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# References

1. R1-2106026, Summary of discussion on PDSCH processing time per Capability 2 and DCI format 1\_0, Moderator (Intel Corporation).
2. R1-2106684, PDSCH processing time per Capability 2 and DCI format 1\_0, Spreadtrum Communications.
3. R1-2107568, On UE processing capability #2 and PDSCH scheduled by DCI 1\_0, Intel Corporation.
4. R1-2107677, Processing time for PDSCH scheduled by DCI format 1\_0, Huawei, HiSilicon.
5. R1-2107995, Capability 2 and fallback DCI format 1-0 PDSCH handling, Ericsson.

# Appendix

**Table A-1: Summary of Options for Rel-15 and Rel-16 on Cap 2 and DCI format 1\_0 [1]**

|  |  |  |
| --- | --- | --- |
| **Option** | **Description** | **Comments** |
| **Option A** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., w/o additional DMRS)***   + For a PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + The UE does not expect to be scheduled with a unicast PDSCH by DCI format 1\_0 with *ld > 7* or *ld > 4* symbols for mapping types A or B respectively in the cell   + **No NBC issue \*\***   + **Severe scheduling constraint since unicast PDSCH longer than 7 symbols and 4 symbols for mapping types A and B respectively cannot be supported with DCI 1\_0** |
| **Option A1** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***All PDSCHs subject to HARQ-ACK feedback (“unicast PDSCHs”) that may be scheduled in the DL cell are expected to satisfy conditions for Cap #2 timeline (i.e., with additional DMRS per ‘pos0’ only)***   + For a PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + The UE does not expect to be scheduled with a unicast PDSCH by DCI format 1\_0 ~~with~~ *~~l~~~~d~~ ~~> 7~~* ~~or~~ *~~l~~~~d~~ ~~> 4~~* ~~symbols for mapping types A or B respectively~~ in the cell   + **No NBC issue \*\***   + **Severe scheduling constraint since unicast PDSCH cannot be scheduled using DCI 1\_0** |
| **Option B** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For a PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + The UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of ~~the~~ a unicast PDSCH actually containing additional DMRS that the UE is expected to process   + **No NBC issue \*\***   + **Serious feasibility issue at the UE for Cap #2** |
| **Option B1** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 1 (PDSCH DMRS as per ‘pos2’ for PDSCH RE mapping but UE is not expected to process additional DMRS symbols for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + The UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of ~~the~~ a unicast PDSCH actually containing additional DMRS or not   + The UE is NOT expected to process any additional DMRS   + Existing DMRS mapping and rules are maintained   + **No feasibility issue for UE implementation**   + **UE needs different handling of additional DMRS symbols in general for DMRS per ‘pos2’**   + **This option is NBC to Rel-15 specs** |
| **Option B2** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For all PDSCHs, including PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCHs”) are to follow Cap #2 timeline***   + For PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 3 (PDSCH DMRS as per ‘pos0’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + The UE is expected to satisfy Cap #2 processing times as per Table 5.3-2, regardless of ~~the~~ a unicast PDSCH actually containing additional DMRS or not   + The UE is NOT expected to process any additional DMRS   + **DMRS mapping rule is updated – if Cap #2 is configured and additional DMRS is not configured, then UE assumes DMRS per ‘pos0’ for PDSCH scheduled by DCI 1\_0 subject to HARQ-ACK feedback**   + **No feasibility issue for UE implementation**   + **No need for different handling of additional DMRS symbols for a given DMRS time domain configuration**   + **This option is NBC to Rel-15 specs** |
| **Option C** | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + ***For a PDSCH scheduled by DCI format 1\_0 with ld > 7 or ld > 4 symbols for mapping types A or B respectively, subject to HARQ-ACK feedback (“unicast PDSCH”), the UE may fall back to Cap #1 timeline; other PDSCHs are to follow Cap #2 timeline, subject to any other applicable constraints (e.g., Cap 2 with 136 PRBs constraint for 30 kHz)***   + For a PDSCH scheduled by DCI 1\_0 and subject to HARQ-ACK feedback, DMRS\_Alt 2 (PDSCH DMRS as per ‘pos2’ for both PDSCH RE mapping and channel estimation for PDSCH reception) applies | * For a UE configured with Cap #2 in a DL cell and NOT configured with additional DMRS by higher layers:   + All PDSCH durations can be scheduled by DCI format 1\_0 for unicast PDSCH   + **This option is NBC to Rel-15 specs**   + **Feasibility issue for UE implementation due to overlapping of processing timelines in case a “fast PDSCH” follows a “slow PDSCH” in quick succession** |