**3GPP TSG-RAN WG1 Meeting #106-e R1-2108254**

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

**Agenda item:** 8.1.2.1

**Source:** Moderator (Qualcomm)

**Title:** Summary #2 of email discussions [106-e-NR-feMIMO-03] for mTRP PDCCH enhancements

**Document for:** Discussion/Decision

# **PDSCH mapping Type B**

The following was agreed in GTW:

**Agreement**

Among the two Alts in RAN1 #104b-e agreement on PDSCH mapping Type B, support Alt1 (The candidate that starts later in time).

Also, the following was noted in Chairman’s notes for comeback

**For comeback, at least select one of the following options in Week2**

***For PDSCH processing time in this case, d1,1 is determined***

* ***Option 2: By considering the PDCCH candidate that results in larger d1,1 value***
* ***Option 3: By considering the number of overlapping symbols from both PDCCH candidates.***
	+ ***Each of the overlapping symbol is counted as a single symbol***
* ***Option 4: By considering the number of overlapping symbols from both PDCCH candidates.***
	+ ***Double-counting each PDSCH symbol that overlaps with both PDCCH candidates.***

In the previous rounds of discussions, majority companies (22 companies) supported Option 2 for *d1,1* calculation.

For reference, the existing specification for *d1,1* calculation in the case of PDSCH mapping Type B is copied below:

- For UE processing capability 1: If the PDSCH is mapping type B as given in clause 7.4.1.1 of [4, TS 38.211], and

- if the number of PDSCH symbols allocated is *L* ≥ 7, then *d1,1* = 0,

- if the number of PDSCH symbols allocated is *L* ≥ 4 and *L* ≤ 6, then *d1,1* = 7- *L.*

- if the number of PDSCH symbols allocated is *L* = *3* then *d1,1 = 3 +* min *(d,1)*, where *d* is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.

- if the number of PDSCH symbols allocated is 2, then *d1,1* = 3*+d*, where *d* is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.

- For UE processing capability 2: If the PDSCH is mapping type B as given in clause 7.4.1.1 of [4, TS 38.211],

- if the number of PDSCH symbols allocated is *L* ≥ 7, then *d1,1* = 0,

- if the number of PDSCH symbols allocated is *L* ≥ 3 and *L* ≤ 6, then *d1,1* is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH,

- if the number of PDSCH symbols allocated is 2,

- if the scheduling PDCCH was in a 3-symbol CORESET and the CORESET and the PDSCH had the same starting symbol, then *d1,1* = 3,

- otherwise *d1,1* is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.

It can be seen above that *d1,1* is not the same as d (number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH), and also is not always a function of d. This case in the above is one example where *d1,1* is not a function of d. In addition, in some cases, no matter how large d becomes (as a result of Option 3 or 4), it is capped by value of 1. This case in the above is one example. Hence, the description of Option 3 or Option 4 may require some clarifications.

The following examples may be used for explanations of your answer to the below questions:



**Question 1: Among Options 2, 3, 4 above which one do you prefer? Why?**

**Question 2: How *d1,1* is determined in Option 3 or 4 in this case above (Example 2)?**

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| Company | Comments |
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# **The case that one linked candidate overlaps with an individual candidate**

The following was agreed in the previous meeting:

**Agreement**

When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, select one option among the following in RAN1#105-e:

* Option 1: The individual candidate is not counted for monitoring
	+ Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).
* Option 2: The candidate in a higher SS set ID is not counted for monitoring
	+ Interpretation of the detected DCI depends on which candidate is not counted (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).
	+ FFS: Impact to the other linked PDCCH candidate
* Option 3: The candidate associated with SS set(s) with lower priority is not counted for monitoring, where for two linked SS sets, the priority is according to one of the two SS sets with a lower SS set ID
	+ Interpretation of the detected DCI depends on which candidate is not counted (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).
	+ FFS: Impact to the other linked PDCCH candidate
* FFS: Whether a max limit on number of such overlaps is needed.

Additional specification support may be introduced for the purpose of resolving ambiguity (if any) for interpretation of the detected DCI. For example,

* Distinguished by different RNTIs defined for the linked candidate versus the individual candidate
* Distinguished by aggregation level restrictions that can be expected by the UE in the case of overlap

Views in the first round of discussions are summarized below:

* **Support the proposal, i.e., Option 1: NTT Docomo (depending on overbooking), MediaTek (if “not counted” is changed to “not monitored”), Apple, QC (if UE capability is added), Fujitsu, vivo, ZTE, Nokia/NSB, CMCC, NEC, Huawei/HiSilicon, Convida Wireless, FGI/APT, TCL**
* **Support Option 2: Lenovo/MotM, LG, OPPO, Samsung, InterDigital, CATT, Intel**
* **Support Option 3: NTT Docomo (depending on overbooking), LG, Fraunhofer IIS/HHI, Xiaomi, InterDigital, CATT, E///, Futurewei, Intel**

Option 1 has slight majority support. Also, a good number of companies support Option 3.

Docomo suggested to first decide on overbooking issue. From moderator perspective, this issue has been discussed for a long time now, and a decision may be needed in this meeting.

MediaTek suggested that “not counting for monitoring” should be replaced with “not monitored”. In my understanding, these two are not the same. This is also evident from the GTW agreement for the other issue (dropping or not monitoring does not impact the BD count). I think what we already agreed on is “not counting for monitoring” as copied below, which is same as Rel. 15 rule when CORESET/DCI size/CCEs/scrambling are the same. However, if there is a consensus to change the agreement, it can be discussed. A question is asked below regarding this point.

**Agreement**

When two SS sets are linked for PDCCH repetition, they do not contain individual PDCCH candidates.

* Note 1: For configuration of individual PDCCH candidates, a different SS set can be configured by network.
* Note 2: When one of the linked PDCCH candidates uses the same set of CCEs as an individual PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, Rel. 15 rule is followed wrt not counting an additional BD.

LG and a few other companies suggested to combine Option 2 and Option 3. This does not seem to help since these options are already identified and one needs to be selected. If needed, we can down-select between two options first (instead of first combining options and then separating them again). Given that we have been discussing this issue for multiple meetings now, it is preferred to directly select one option.

Also, the following have been mentioned by companies in the first round:

* Option 1: Simplest solution and less specification impact. Discussions on handling the other (non-overlapped) linked candidates would not be needed.
* Option 2: Reuses priority rule of Rel.15/16, and allows for prioritizing either the linked candidate or the individual candidate
* Option 3: Same priority for linked SS sets, and allows for more flexibility

**Question 1: Do you think “not counted for monitoring” should be changed to “not monitored” in the description of the options?**

**Question 2: Among Option 1 and Option 3, can you accept one option? If yes, which one?**

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# **Details of number of BDs**

In RAN1 #104b-e, the following was agreed:

**Agreement**

For number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, support

* UE reports one [or more] number(s) as required number of BDs for the two PDCCH candidates
	+ Candidate values: 2, 3.
* FFS: Default behaviour
* FFS: Whether one of the candidate values imply that UE supports soft combining
* FFS: Whether additional candidate values are supported (e.g. non-integer numbers)
* FFS: RRC configuration based on reported UE capability

In GTW, the following proposal and conclusion were discussed without an agreement:

***FL Proposal 4:***

***RRC configuration for counting two linked PDCCH candidates as 3 BDs is supported.***

* ***It can be configured only if UE indicates 3 BDs.***
* ***~~When 3 BDs are supported and configured, it implies UE performs soft combining.~~***
	+ ***~~FFS: Any impact on RAN1 specification~~***
* ***If not configured, 2 BDs are assumed.***

***Proposed conclusion:***

***When 3 BDs are supported and configured, it implies UE performs both soft combining and individual decoding.***

Views from the previous round of discussions on the general proposal is summarized below:

* **Support the proposal (): NTT Docomo, MediaTek, QC (w/o second bullet), Lenovo/MotM, Fujitsu, OPPO (w/o second/third bullets), Xiaomi, Samsung (w/o second bullet), vivo, ZTE, E///, CMCC, NEC, Huawei/HiSilicon, Convida Wireless, FGI/APT, TCL, Futurewei (with some additions), Intel**
	+ **Clarification for soft combining for 2 BDs: LG, Fraunhofer IIS/HHI, Spreadtrum, InterDigital, CATT**
* **Do not support: Apple, Nokia/NSB**

It may be helpful to first clarify the intention of the proposal:

**Question 1: If UE indicates 3BDs, is it expected that the UE also supports 2BDs?**

**Question 2: If the answer to Q1 is no, then should the UE be able to indicate that it supports both 2BDs and 3 BDs? i.e., In RAN1 #104b-e Agreement mentioned above “[or more]” is needed?**

**Question 3: If the answer to either of Q1 or Q2 is yes, should we support RRC configuration for 2 BD versus 3 BD?**

**Question 4: For 3BDs, should UE perform both individual decoding as well as soft combining?**

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# **Overbooking**

Views on different alternatives for Case1/Case2 in the first round are summarized below:

* **Case 1:**
	+ **Alt1: QC, LG, OPPO, Xiaomi, Spreadtrum, vivo, ZTE, ASUSTeK, E///, Nokia/NSB, CMCC, NEC, Convida Wireless, FGI/APT, Futurewei, Intel (depending on 2.4)**
	+ **Alt2: NTT Docomo (or Alt2a), MediaTek, Apple, Lenovo/MotM, Fujitsu, InterDigital, CATT, ASUSTeK, Huawei/HiSilicon, TCL, Futurewei**
	+ **Alt3: CATT**
* **Case 2:**
	+ **Alt1-1: vivo, ASUSTeK, FGI/APT**
	+ **Alt1-2: QC, LG, OPPO, ZTE, ASUSTeK, E///, Nokia/NSB, CMCC, NEC, Convida Wireless, FGI/APT**
	+ **Alt1-3: ASUSTeK, E///**
	+ **Alt2: NTT Docomo (or Alt2a), MediaTek, Apple, Lenovo/MotM, Fujitsu, Xiaomi, InterDigital, CATT, ASUSTeK, Huawei/HiSilicon, TCL, Futurewei**
	+ **Alt3: CATT**

Further discussions are needed. Firstly, Alt3 can be removed. Second, Alt1-3 can be also removed given that companies supporting it, also support other alternatives. This will help more focused discussions. Third, as Docomo mentioned, in Alt2, the priority between linked SS sets and individual SS sets can be also considered.

The following have been observed from the responses in the first round:

* Proponents of Alt1: Less specification impact and consistency with legacy overbooking, smaller probability of PDCCH dropping (instead of increasing granularity of dropping)
* Proponents of Alt2: Not breaking the link between two SS sets, unified solution for Case 1 and Case 2.

Given that there is no clear majority between Alt1 and Alt2, more discussions are invited so that companies understand each other better. We can try to do the down-selection in this meeting or the next meeting. At least for Case 2 (3BDs), one of the alternatives is needed.

***FL Proposal 5: For overbooking in the PCell for USS with two linked SS sets in the same slot/span, select one Alt for each of Case 1 and Case 2 in RAN1 #106-bis-e:***

* ***Case 1: 2 BDs are counted for two linked candidates:***
	+ ***Alt1: No change (use existing spec)***
	+ ***Alt2: Consider the SS set pair together (both are kept or both are dropped), where the priority is based on lower SS set ID among the pair.***
	+ ***~~Alt3: Overbooking is done per linked candidate / linked MO (rather than per SS set level)~~***
* ***Case 2: 3 BDs are counted for two linked candidates:***
	+ ***Alt1: Overbooking is per individual SS set as in Rel. 15/16***
		- ***Alt1-1: The third BD is counted as a virtual SS set (i.e., the virtual SS set for the third BDs is dopped before dropping the linked SS sets).***
		- ***Alt1-2: The third BD is counted as part of the SS set with higher ID.***
		- ***~~Alt1-3: Each SS set is assumed to contain half of the total BDs~~***
	+ ***Alt2: Consider the SS set pair together (both are kept or both are dropped), where the priority is based on lower SS set ID among the pair.***
	+ ***~~Alt3: Overbooking is done per linked candidate / linked MO (rather than per SS set level)~~***
* ***FFS: Inter-span PDCCH repetition for r16monitoringcapablity.***

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# **Determination of two QCL-TypeD**

Based on the following agreement, companies discussed the details of required enhancements to identify two QCL-TypeD properties for multiple overlapping CORESETs.

**Agreement**

For a UE supporting reception with two different beams, support identifying two QCL-TypeD properties for multiple overlapping CORESETs

* FFS: How to enhance existing QCL-TypeD priority rules for overlapping CORESETs
* Note: The primary goal of this enhancement for the purpose of this sub-AI is to support time-overlapping PDCCH repetitions in FR2.

The following alternatives were discussed:

* Alt1: Identify the two QCL-Type D properties based on legacy priority order:
* Alt2: Reuse legacy priority rule to identify the first QCL-TypeD properties, and then, identify the second QCL-TypeD according to one of the SS set that is linked with the SS set with the first QCL-TypeD
* Alt3: Assign same priority for two linked search space sets for PDCCH transmission with overlapping monitoring occasions (and linked SS sets in USS have higher priority than individual SS set)
* Alt4: Based on group beam pair reported by the UE for simultaneous reception
* Alt5: First CORESET is determined among unlinked candidates; second CORESET is determined among linked candidates:

Views on different alternatives in the first round of discussions are summarized below:

* **Alt 1: LG, OPPO, InterDigital, ZTE, Nokia/NSB**
* **Alt 2: NTT Docomo, MediaTek, QC, Fujitsu, Samsung, CATT, Nokia/NSB, CMCC, Huawei/HiSilicon, TCL, Futurewei, Intel**
* **Alt 3: NTT Docomo, MediaTek, Lenovo/MotM, Xiaomi, Samsung, vivo, CATT, Ericsson, CMCC, FGI/APT, TCL**
* **Alt 4: Apple**
* **Alt 5: Spreadtrum**

Further discussions are needed. First, I suggest to remove option 4 and 5 as they are supported by a single company. Option 4 requires a different framework than Rel. 15/16 for QCL-TyeD prioritization. For Option 5 (grouping the CORESETs into linked and individual and select one QCL-TypeD from each), it does not result in two FDM PDCCH repetitions to be monitored, and the procedure is complicated (unlike Alt1).

Also, some clarifications for details of Alt2 and Alt3 are added below based on the responses in the first round of discussions. The intention of the following proposal is to clearly list the alternatives. The (down)select of the alternative can happen in the next meeting

***FL Proposal 6: For a UE supporting reception with two different beams and configured with PDCCH repetitions, for determination of two QCL-TypeD properties for multiple overlapping CORESETs, select one Alt in RAN1 #106-bis-e:***

* ***Alt1: Identify the two QCL-Type D properties based on legacy priority order.***
* ***Alt2: Reuse legacy priority rule to identify the first QCL-TypeD property, and then, identify the second QCL-TypeD according to one of the SS sets that is linked with a SS set with the first QCL-TypeD (among the multiple overlapping CORESETs)***
	+ ***In the case of multiple such SS set pairs, Rel. 15 priority order is followed for the second QCL-TypeD determination***
	+ ***FFS: The case of no such SS set pair***
* ***Alt3: Assign same priority for two linked search space sets for PDCCH transmission with overlapping monitoring occasions (and linked SS sets in USS have higher priority than individual SS set). Theses priority rules combined with Rel. 15 priority order determine the two QCL-TypeD.***
	+ ***FFS: The case that the first QCL-TypeD is from unlinked CSS***
	+ ***FFS: The case of no linked SS sets among the multiple overlapping CORESETs***

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# **CORESETPoolIndex**

The issue of using PDCCH repetitions with multi-DCI based mTRP was discussed in the previous meeting, and some companies preferred more time for studying the issue. There are three alternatives discussed in the contributions:

* Alt1: Support two linked PDCCH candidates to be associated with two CORESETPoolIndex values.
	+ For this Alt, some Rel. 16 multi-DCI based mTRP rules need to be revisited such as scrambling, CRS rate matching, HARQ-Ack, BD counting, etc. For example, a reference candidate is needed for PDSCH scrambling or CRS rate matching.
* Alt2: Two linked PDCCH candidates are not expected to be associated with different CORESETPoolIndex values.
	+ This Alt does not prevent simultaneous configuration of multi-DCI and CORESETPoolIndex as long as linked candidates are associated with the same CORESETPoolIndex
* Alt3: CORESETPoolIndex value is not expected to be configured if PDCCH repetition is configured in the same CC.
	+ This Alt prevents simultaneous configuration of multi-DCI and PDCCH repetition.

Views on the three alternatives are summarized below:

* **Alt1: LG, Fraunhofer IIS/HHI, Samsung, ZTE, CATT, NEC, Futurewei**
* **Alt2: NTT Docomo, Apple, QC, Lenovo/MotM, Fujitsu, Xiaomi, Spreadtrum, InterDigital, Vivo (with some restriction), Nokia/NSB, CMCC, Huawei/HiSilicon, Convida Wireless, TCL, Futurewei, Intel**
* **Alt3: MediaTek, Apple, Lenovo/MotM, OPPO, Spreadtrum, Vivo, E///**

Given that Alt2 has majority support, it is suggested below. It should be noted that Alt2 or Alt3 do not have further specification impact, but Alt1 requires some further work/agreements.

***FL Proposal 8: Two linked PDCCH candidates are not expected to be associated with different CORESETPoolIndex values.***

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# **Complexity handling related to numbers / locations of linked candidates**

Based on the discussions in the first round, majority of companies agree with the issue or are open to study it further. More details may be needed on the solution to handle various cases. The details can be discussed in the next meeting given that there are not many specifics at this point.

***FL Proposal 11: Study whether/how to handle UE complexity / memory requirements for linked PDCCH candidates***

* ***The following cases can be considered:***
	+ ***Case 1: One pair of linked MO’s of one pair of linked SS sets in a given slot with large number of candidates.***
	+ ***Case 2: Multiple pairs of linked MO’s of one pair of linked SS sets in a given slot, where MO’s of the two SS sets are not interlaced (similar to Case 2 in the figure above)***
	+ ***Case 3: For two pairs of linked SS sets (e.g. SS sets 1 and 2 are linked, and SS sets 3 and 4 are linked), a MO of any of the SS sets (e.g. SS set 3) is in between two linked MOs of another two SS sets (e.g. SS sets 1 and 2).***
	+ ***Other cases are not precluded.***
* ***Examples of possible mechanisms to address the issue: Restrictions in the spec, UE capability, limit total number linked candidates in a slot, limit total number of linked candidates / CCEs at any given time (similar to CPU occupation)***
* ***Whether the solution should also depend on AL of linked candidates***
* ***The case of CA can also be considered***

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# **Inter-slot PDCCH repetition**

This issue has been discussed multiple times without a clear conclusion or agreement. In this meeting, multiple companies (ZTE, NEC, Xiaomi, Intel) proposed to support inter-slot PDCCH repetition in addition to intra-slot case. We need a resolution in this meeting. For the case of inter-span PDCCH repetition, it will be separately discussed (see FFS in the Proposal in Section 4).

**Question: Do you support inter-slot PDCCH repetition?**

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# **CSS for PDCCH repetition**

Views based on the contributions are summarized below:

* Convida, Ericsson, and Qualcomm propose to discuss some of the DCI formats 2\_x (CSS Type3).
* Vivo and Lenovo/MotM proposed to discuss whether different CSS types (0/0A/1/2) are supported for PDCCH repetition or not.
* Fraunhofer: QCL assumption for PDCCH with RA-RNTI and scheduled PDSCH with CFRA-based PDCCH order.

CSS Type 3 is configured in RRC connected, and the existing framework is applicable. Also, the following was concluded before:

**Conclusion**

Group-common DCI formats (DCI formats 2\_x) are not precluded for multi-TRP PDCCH reliability enhancements and can be discussed with a lower priority compared to UE-specific DCI formats.

Note: Enhancements required for DCI formats 2\_x, if any, can be discussed case-by-case.

Hence, for CSS Type 3, the required clarifications are related to specific procedures in DCI format 2\_x (e.g. timeline conditions, reference PDCCH candidate).

Regarding CSS Type 0/0A/1/2, the possible applicability to PDCCH repetition may be limited to RRC connected mode (given that configuration of SS set linking is needed). Also, the existing configuration of SS sets for these CSS types are slightly different than USS or CSS Type3 as shown below:



With respect to the point mentioned by Fraunhofer, the following specification texts are noted, which means that the PDCCH order and the DCI with RA-RNTI and the scheduled PDSCH have the same beam

38.214: When receiving a PDSCH scheduled with RA-RNTI in response to a random access procedure triggered by a PDCCH order which triggers contention-free random access procedure for the SpCell [10, TS 38.321], the UE may assume that the DM-RS port of the received PDCCH order and the DM-RS ports of the corresponding PDSCH scheduled with RA-RNTI are quasi co-located with the same SS/PBCH block or CSI-RS with respect to Doppler shift, Doppler spread, average delay, delay spread, spatial RX parameters when applicable.

38.213: If the UE attempts to detect the DCI format 1\_0 with CRC scrambled by the corresponding RA-RNTI in response to a PRACH transmission initiated by a PDCCH order that triggers a contention-free random access procedure for the SpCell [11, TS 38.321], the UE may assume that the PDCCH that includes the DCI format 1\_0 and the PDCCH order have same DM-RS antenna port quasi co-location properties.

This is illustrated in the figure below if my understanding of the above is correct:



When the PDCCH order is transmitted by PDCCH repetitions with two different beams, some discussions seem to be necessary as to how the beam of the DCI with RA-RNTI and the scheduled PDSCH are selected.

**Question 1: Which of the following CSS types should / should not be supported for PDCCH repetition in Rel. 17?**

* **CSS Type3 (DCI formats 2\_x)**
* **CSS Type0/0A/1/2 in RRC connected**

**Question 2: Do you agree with the issue mentioned by Fraunhofer and described above? If yes, what is your preferred solution?**

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# **Issues related to BFR**

Apple mentioned the following in their contribution:

* Support UE to report 2 new beams in BFRQ for PCell/SCell BFR, and after UE receives BFR response it can apply the 2 beams for reception of PDCCH repetition with 2 beams
* SS-BFR should not be linked with other SS for PDCCH repetitions

At least for the second issue, my understanding is that some discussions are needed. This is because “recoverySearchSpaceId” is specifically configured for BFR response, and the CORESET associated with this SS set cannot be used for any other SS set. Also, the beam of that CORESET is based on q\_new (new identified beam after BFR). Hence, some questions are asked below:

**Question 1: Can the recoverySearchSpaceId be linked with another SS set (for PDCCH repetition of BFR response on the PCell)?**

**Question 2: If answer to Q1 is yes, can the linked SS set be associated with the same BFR-CORESET (PDCCH repetition with same beam) or can be associated with a different CORESET?**

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# **AP-CSI-RS scheduled by PDCCH repetition**

In GTW, the following was agreed for PDSCH with mapping Type B:

**Agreement**

Among the two Alts in RAN1 #104b-e agreement on PDSCH mapping Type B, support Alt1 (The candidate that starts later in time).

Qualcomm proposed in their contribution to have a similar restriction for AP-CSI-RS scheduled by PDCCH repetitions. In Rel. 15, both cases of PDSCH mapping Type B and AP-CSI-RS have similar restriction”

The UE is not expected to receive a PDSCH with mapping type B in a slot, if the first symbol of the PDCCH scheduling the PDSCH was received in a later symbol than the first symbol indicated in the PDSCH time domain resource allocation.

The UE does not expect that aperiodic CSI-RS is transmitted before the OFDM symbol(s) carrying its triggering DCI.

The following was suggested by Qualcomm: For AP-CSI-RS scheduled by two PDCCH candidates that are linked for repetition, the UE does not expect that the AP-CSI-RS is transmitted before the first symbol of the PDCCH candidate that starts later in time.

**Question: Do you agree with the issue mentioned above for AP-CSI-RS scheduled by PDCCH repetitions?**

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