**3GPP TSG RAN WG1 Meeting #102-e R1-200xxxx**

**e-meeting, August 17th – 28th, 2020**

**Agenda item:** 8.1.2.1

**Source:** Qualcomm Incorporated

**Title:** Discussion Summary for mTRP PDCCH Reliability Enhancements

**Document for:** Discussion/Decision

# **Introduction**

In the previous round of discussions, Proposals 2-4 were discussed summarizing different multiplexing schemes / alternatives to enable PDCCH with two TCI states / options for PDCCH transmission at high-level. The new proposals below (Proposals 5-8) get into the next level of details.

# **New Proposals**

Some companies provided comments about sub-alternatives (in proposal 3) as well as how different alternatives / sub-alternatives can be combined with different options of proposal 4.

## **Proposal 5**

For Alt 1 in Proposal 3, HW / LG / CATT suggested or supported to add two sub-alternatives:

o Alt 1-1: One candidate/search space set within one CORESET with two active TCI states

o Alt 1-2: Two candidates/search space sets within one CORESET with two active TCI states

In case of Alt 1-2, if two SS sets are used, then it is not clear why we need a CORESET with 2 TCI states. This would be like combining Alt1 and Alt3, and can complicate the discussions further. Hence, FL’s suggestion is focus on “PDCCH candidate” for Alt 1-1 and Alt 1-2. Furthermore, using “two PDCCH candidates” in Alt 1-2 does not mean to imply how the limit toward the BD limit is determined, which needs to be further studied. Hence, FFS is added.

***Proposal 5: For Alt 1 (one CORESET with two active TCI states), study the following***

* ***Alt 1-1: One PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET.***
* ***Alt 1-2: Two PDCCH candidates (in a given SS set) are associated with the two TCI states of the CORESET, respectively***
  + ***FFS: How the two PDCCH candidates should be counted toward the BD limit***

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| Company | Comments |
| DOCOMO | Support the proposal |
| MediaTek | If two SS sets are used associated with one CORESET with 2 TCI states, we can save the limited number of CORESETs. Each SS set can be assigned with different TCI state in this case. Also, it is easier to configure a TCI state for the SS set level instead of the PDCCH candidate level. Thus, it can be a viable option. We suggest to keep the original Alt 1-2 as follows. We also would like to separate original Alt1-1 to current FL’s suggestion because two schemes are actually different. We also suggest to revise “Two PDCCH candidates” to “Two sets of PDCCH candidates” in order not to preclude more than 2 repetitions.  ***For Alt 1 (one CORESET with two active TCI states), study the following***   * ***Alt 1-1: One PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET.*** * ***Alt 1-2: Two sets of PDCCH candidates (in a given SS set) are associated with the two TCI states of the CORESET, respectively***   + ***FFS: How the two PDCCH candidates should be counted toward the BD limit*** * ***Alt 1-3: Two sets of PDCCH candidates (Each set of PDCCH candidates in a corresponding SS set) within one CORESET with two active TCI states*** |
| vivo | MediaTek’s revisions looks good. Furthermore, the parameter ’nrofCandidates’ of the search space in 38.331 is limited into a monitoring occasion, and different candidates is distinguished by aggregation level and CCE start index.  In our view Alt1-2 includes following 2 cases:  Case1: Two PDCCH candidates with different AL  Case2: Two PDCCH candidates belonging to different monitoring occasions (in a given SS set) regardless of same or different start index of CCE. |
| Huawei, Hisilicon | Support the proposal in general.  In addition, we are not sure whether there is any impact to BD limit for alt 1-1, therefore, we suggest to move the FFS of BD limit to be a sub-bullet of the main bullet (i.e., in parallel with alt1-1 and 1-2). |
| Convida Wireless | Support the proposal and the revision from MediaTek is fine.  However, we suggest removing the FFS about the counting towards the BD limit. This issue will undoubtedly have to be discussed once the details of supported scheme(s) are more clear. It is not necessary to presently include this particular FFS point everywhere, given that so much is for further study. |
| Nokia/NSB | Mediatek suggestion looks ok.  Also, agree with HW on the FFS part, as that should be valid to the main bullet, not only to Alt 1-2. |
| Futurewei | Support the proposal with MediaTek’s revision and Huawei’s comment.  For Alt1-1, should “one PDCCH candidate” also be changed to “one set of PDCCH candidates”? |
| LG | Support the proposal with MediaTek’s revision. |
| Lenovo/Motorola Mobility | Support the proposal of MediaTek’s version with removing FFS part of Alt 1-2. |
| Apple | Support FL’s original proposal. It looks Alt1-3 proposed by MTK does not belong to this category, which seems like Alt3. |
| ZTE | MediaTek’s revision seem good for us. |
| Samsung | Regarding revised proposal from MediaTek, the wording “two sets of” in order not to preclude more than 2 repetitions should be clarified more. Does it mean PDCCH candidates repeated within a set or repeated across sets? |
| Sharp | Support the proposal with MediaTek’s revision |
| OPPO | Fine with MediaTek’s revision |
| Xiaomi | Support the proposal with MediaTek’s revision |
| CATT | Agree to add Alt1-3.  We have one question for clarification: can both SFN and option 1 be supported with Alt1-1?  The linkage issue should also be discussed for Alt 1 and 2 as in Alt 3. |
| CMCC | Support the proposal with MediaTek’s revision with removing FFS part of Alt 1-2.  From our understanding, Alt 1-3 is different from Alt 3, Alt 1-3 means two SS sets associated with one CORESETs, while Alt 3 includes the case that two SS sets associated with two CORESETs.  For each alternative, there are many issues left for further discussion, at this stage, we think it is unnecessary to list BD limit here. |
| Fraunhofer IIS/HHI | Support addition of Alt 1-3 from MediaTek |
| Ericsson | Support the proposal with the revision from MediaTek |

FL update:

MediaTek added Alt 1-3, and is supported by most other companies. Hence it is added in the updated proposal with the clarification that each SS set is associated with only one TCI state of the CORESET.

Vivo mentioned two cases to enable Alt 1-2. The details of how each alternative can be supported can be brought up by supporting companies in the next meeting.

Huawei / Hisilicon commented that Alt 1-1 may have impact on BD, but Alt 1-1 is about one PDCCH candidate. Hence, it is associated with one BD only. Given that Proposal 3 (which is agreed) already mentions the impact on BD, then it should be ok to not mention that here. Hence, sub-bullet is deleted.

Regarding Futurewei’s comment on “one set of PDCCH candidates” in Alt 1-1, the point of Alt 1-1 per my understanding is that a PDCCH candidate is self-contained in the sense that different REGs or RE bundles or CCEs have different TCI states. Hence, one set of PDCCH candidates changes the intention.

Samsung asked for a clarification of “set of” PDCCH candidates. FFS is added below as whether/how set is defined is not clear at this stage.

Regarding CATT’s question, my understanding is yes. For SFN, this is discussed in Proposal 8.

Also, CATT and Samsung mentioned that linkage can be applicable to other Alts (e.g. Alt 1-2/1-3 below as well as Alt 2). Next proposal (Proposal 6) is modified to capture this more generally.

***Updated Proposal 5: For Alt 1 (one CORESET with two active TCI states), study the following***

* ***Alt 1-1: One PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET.***
* ***Alt 1-2: Two sets of PDCCH candidates (in a given SS set) are associated with the two TCI states of the CORESET, respectively***
  + ***~~FFS: How the two PDCCH candidates should be counted toward the BD limit~~***
* ***Alt 1-3: Two sets of PDCCH candidates are associated with two corresponding SS sets, where both SS sets are associated with the CORESET and each SS set is associated with only one TCI state of the CORESET***
* ***FFS: For Alt 1-2 and 1-3, whether “set” is needed, and if yes, the relationship between intra-set and inter-set PDCCH candidates***

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| Company | Comments |
| MediaTek | Support the proposal. To answer the question from Samsung, PDCCH candidates are repeated across sets. One set of PDCCH candidates is associated with a SS set. I think modified version by FL is now clearer. Do you need more clarification? |

## **Proposal 6**

For Alt 3 in Proposal 3, two sub-alternatives were discussed in the previous round as:

* Alt3-1: Two candidates in different SS sets are explicitly linked together creating one PDCCH candidate (i.e. UE knows the linking before decoding)
* Alt3-2: Two candidates in different SS sets are not explicitly linked together (i.e. UE does not know the linking before decoding)

MediaTek asked “For Alt3-1, does this include both one joint encoding for one PDCCH candidate and mapped to each SS set and two separate encoding (including repetition) with linkage? For Alt3-2, does this mean selection decoding of two candidates because the UE doesn’t know the linkage of two candidates?”

From FL’s point of view, Alt3-2 means selection decoding without possibility of soft combining while Alt3-1 allows for soft combining. Alt3-1 does not necessarily mean joint encoding / rate matching (repetition is actually more natural for Alt3-1). Hence, the description of “creating one PDCCH candidate” is removed in Proposal 6 to avoid ambiguity. Similar to Proposal 5, whether the two PDCCH candidates in Alt3-1 are counted toward the BD limit needs further study. Note that proposal 6 does not talk about combinations with different options yet (that is the subject of Proposal 7).

***Proposal 6: For Alt 3 (two SS sets associated with corresponding CORESETs), study the following***

* ***Alt 3-1: Two PDCCH candidates in the two SS sets are explicitly linked together (UE knows the linking before decoding)***
  + ***FFS: How the two PDCCH candidates should be counted toward the BD limit***
* ***Alt 3-2: Two PDCCH candidates in the two SS sets are not explicitly linked together (UE does not know the linking before decoding)***

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| Company | Comments |
| DOCOMO | Support the proposal |
| MediaTek | Thanks for the clarification. With the same reason, we suggest to revise as follows.   * ***Alt 3-1: Two sets of PDCCH candidates in the two SS sets are explicitly linked together (UE knows the linking before decoding)***   + ***FFS: How the two PDCCH candidates should be counted toward the BD limit*** * ***Alt 3-2: Two sets of PDCCH candidates in the two SS sets are not explicitly linked together (UE does not know the linking before decoding)*** |
| vivo | MediaTek’s revision looks fine.  We also think Alt3 is more suitable for separate encoding scheme other than SFN and joint encoding. |
| Huawei, Hisilicon | Support the proposal in principle.  Similar to our comment to proposal 5, we are not sure whether there is any impact to BD limit for alt 3-2, therefore, we suggest to move the FFS of BD limit to be a sub-bullet of the main bullet (i.e., in parallel with alt 3-1 and 3-2). |
| Convida Wireless | Support the proposal and the revision from MediaTek is fine.  However, we suggest removing the FFS about the counting towards the BD limit. This issue will undoubtedly have to be discussed once the details of supported scheme(s) are more clear. It is not necessary to presently include this particular FFS point everywhere, given that so much is for further study. |
| Nokia/NSB | Support the FL proposal. Also, fine to remove FFS as it is mentioned in proposal 3. |
| Futurewei | Support the proposal in general, with MediaTek’s revision and Huawei’s comment.  For the sentence “UE does not know the linking before decoding”, does it imply that a link needs to be designed and the linking will be known by the UE after the decoding of one or both candidates? Can this be clarified? |
| LG | Support the proposal with MediaTek’s revision. |
| Lenovo/Motorola Mobility | Support the FL proposal with removing FFS part of Alt 3-1. |
| Apple | We do not know Alt 3-2 work. If UE does not know the linkage, how can UE know the two PDCCHs are repetitions or not? |
| ZTE | We are fine with FL proposal    @Futurewei, Apple for Alt3-2, our view is UE has to know the link after decoding if UE successfully receives both DCIs which outcome the same result, e.g. PUSCH. Then UE can ignore one. Otherwise, UE behavior will be unclear since UE may not transmit two PUSCHs in a same time. |
| Samsung | Same as in proposal 5, the wording from MediaTek “two sets of” in order not to preclude more than 2 repetitions should be clarified more.  Also, if the linkage means an indication on which PDCCH candidates are repeated, then we think that this proposal can be extended to Alts 1 and 2. |
| Sharp | Support MediaTek’s proposal with MediaTek’s revision |
| OPPO | Fine with MediaTek’s revision |
| Xiaomi | Support the proposal with MediaTek’s revision |
| CATT | For Alt 3, we think the terminology linkage should be clarified before further discussion.  In our opinion, restriction such as the same PDCCH candidate index with the same AL between two candidates can also be viewed as some kind of implicit linkage. Even this is not signaled to UE explicitly, the UE also knows the linkage before decoding.  Agree with Samsung that linkage issue is also related to Alt 1 and 2. |
| CMCC | Support the FL proposal with removing FFS part of Alt 3-1.  Similar to our comment to proposal 5, for each alternative, there are many issues left for further discussion, at this stage, we think it is unnecessary to list BD limit here. |
| Fraunhofer IIS/HHI | The term ‘linked’ should be clarified further. Even for selective decoding, the UE may be indicated explicitly or there may be an implicit connection between the SS sets, like pointed out by CATT, so that the PDCCH candidates in only one of the SS sets is required to be decoded by the UE. |
| Ericsson | Support MediaTek’s revision |

FL update:

Samsung / CATT pointed out that the two cases mentioned in Proposal 6 may be applicable also to Alt 1-2, Alt 1-3, and Alt 1-3 (in addition to Alt 3). Hence, proposal 6 is revised as follows in a more generic way.

MediaTek suggested to not limit to two PDCCH candidate (for more than 2 repetitions), which is captured below. The word “set” here is not used since there is no need to associated those to TCI states (unlike in proposal 5).

FFS part on BD is removed as suggested by multiple companies, and to be consistent with Proposal 5, with the understanding that it should be studies for all alternatives / options / cases.

Regarding Futurewei and Apple’s comments, my understanding is that after decoding, UE needs to identify if one DCI should be discarded in Case 2. As discussed in the Emails, this may not work very well for some DCI formats. For this, FFS is added below.

CATT commented that linkage should be clarified wrt whether it is signaled to the UE or not. Hence, FFS is added.

***Updated Proposal 6: For Alt 1-2/1-3/2/3 ~~(two SS sets associated with corresponding CORESETs)~~, study the following***

* ***Case 1 ~~Alt 3-1~~: Two (or more) PDCCH candidates ~~in the two SS sets~~ are explicitly linked together (UE knows the linking before decoding)***
  + ***~~FFS: How the two PDCCH candidates should be counted toward the BD limit~~***
  + ***FFS: Whether the explicit linkage is signalled to the UE or is fixed.***
* ***Case 2 ~~Alt 3-2~~: Two (or more) PDCCH candidates ~~in the two SS sets~~ are not explicitly linked together (UE does not know the linking before decoding)***
  + ***FFS: Whether this case can support all DCI formats***

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| Company | Comments |
| MediaTek | We are fine with the proposal. Just for clarification on FFS in case 1, does this FFS mean that we need to introduce dynamic signaling like DCI or MAC CE for the linkage or not? |

## **Proposal 7**

Some companies discussed aspects related to combinations of proposal 3 and 4 in the previous round. Given additional sub-alternatives discussed above in Proposals 5 and 6, it may make sense to start talking about how each of those can be combined with different options with respect to PDCCH transmission of proposal 4. Since proposal 4 is related to non-SFN based schemes, the discussions here can focus on TDM and FDM. SFN is discussed separately below (see Proposal 8).

Next proposal discusses combinations of Alts in proposals 3, 5, 6 (Alt 1-1 / 1-2 / 2 / 3-1 / 3-2) with options in proposal 4 (option 1 / 2 / 3). Without further restrictions, there are 5 (different Alts)\*3 (different options)=15 cases for each of TDM and FDM schemes, which may make it difficult to down-select in future meetings. Hence, from FL’s perspective, it is preferred if we can focus only on the combinations that make more sense or are more natural. Note that Alt2 in theory can be combined also with Option 1, but one/joint rate matching across different CORESETs may not be natural and has more spec impact, and hence, is not listed. It can be added if companies think it should be considered. For Alt 3-1, Option 2 is the natural choice, but CATT pointed out that explicit linking can be beneficial even for option 3. Hence both Options 2 and 3 are listed for Alt 3-1. The proposal below is based on initial thinking from FL side as well as some comments in the previous round, and requires further discussions. Hence, the proposal will be further refined based on companies inputs.

***Proposal 7: Consider the following combinations for non-SFN schemes:***

* ***Alt 1-1 + Option 1***
* ***Alt 1-2 + Options 2/3***
* ***Alt 2 + Options 2/3***
* ***Alt 3-1 + Options 2/3***
* ***Alt 3-2 + Option 3***

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| Company | Comments |
| DOCOMO | At this stage, as a high-level proposal, we think Alt.3-2 + Option 2 can also be included. |
| MediaTek | We agree with FL that it is better to associate each alternative with the decoding scheme to reduce the number of possible schemes. Basically we support FL’s proposal. Reasonable combinations can be further studied. We don’t think Alt 3-2 + Option 2 added by DOCOMO is a possible combination. |
| vivo | Compared to Alt3-1, we think the important aspect is that gNB can enable flexible configuration and implementation with Alt3-2, especially in the case of conceivable congestion of PDCCH resources in this serving cell. The gNB can cancel one of two SS sets to avoid the collision with other user’s PDCCH, which is transparent to UE, regardless of PDCCH transmission with option2 or option3.  So we also agree with to include Alt.3-2 + Option 2 |
| Huawei, Hisilicon | We think Alt 3-1 + option 1 can also be studied at this stage, as with the explicit association, the encoded bits can be mapped sequentially to the two candidates, which may be beneficial in some cases such as small to medium AL.  ***Proposal 7: Consider the following combinations for non-SFN schemes:***   * ***Alt 1-1 + Option 1*** * ***Alt 1-2 + Options 2/3*** * ***Alt 2 + Options 2/3*** * ***Alt 3-1 + Options 1/2/3*** * ***Alt 3-2 + Option 3*** |
| Convida Wireless | Support the FL proposal. |
| Nokia | This is good suggestion. But, we think that companies could study the feasibility of the combinations and we should not limit the studies done by the companies till next meeting. . |
| Futurewei | At this stage, we support to include as many combinations as possible. |
| LG | Support the proposal. |
| Lenovo/Motorola Mobility | Support FL proposal. Down selection can be made in the next meeting(s) with more technical analysis. |
| Apple | OK with the proposal |
| ZTE | We propose to change ‘consider’ to ‘study’, some other combinations should not be precluded since the details are not clear so far, e.g. which combination can support FDM, TDM or FDM+TDM. If possible, it is better to add more details about multiplexing schemes in the sub-bullet like as   * Alt 1-1 + Option 1: ( support one of FDM and TDM ) * Alt 1-2 + Options 2/3 ( support one of FDM and TDM ) * Alt 2 + Options 2/3 ( support TDM) * Alt 3-1 + Options 2/3 (support FDM, TDM or FDM+TDM) * Alt 3-2 + Option 3 (support FDM, TDM or FDM+TDM) |
| Samsung | As long as considering combination schemes, we also support to include as many combinations as possible. |
| Sharp | Support the proposal |
| OPPO | Although we doubt the applicability of “Alt 3-2 + Option 3” for group-common DCI format, we can live with it for further discusison |
| Xiaomi | Support the proposal |
| CATT | Agree to study as many combinations as possible at this stage. |
| CMCC | We support to consider the combinations, but it is better to discuss the available combinations at next meeting. |
| Fraunhofer IIS/HHI | The considered combinations need not be restricted now. Companies may study any number of possible combinations until next meeting. The options can be narrowed down then. |
| Ericsson | Support in principle but I think we need to be cautious not to exclude any potential good scheme. Can we stay “Consider at least..” This gives companies a clear study focus while still opening up for discussion on other combinations. |

FL update:

From the response so far, it seems that companies prefer to discuss this in the next meeting. In order to not increase the load on delegates for extensive discussions on this aspect, and to allow more time for companies, I suggest to not consider Proposal 7 in this meeting anymore. However, please feel free to continue the discussions on possible combinations to align the understanding further.

## **Proposal 8**

For SFN scheme (in proposal 2), many companies mentioned that the most natural / viable alternative is Alt1 in proposal 3. Given further sub-alternatives 1-1 and 1-2, SFN is applicable to Alt 1-1. Hence, the following proposal is drafted to narrow the focus for SFN. For the input, the focus should not be on whether a company supports SFN or not. Instead, please comment if you agree with the proposal, and if not, please explain how other alternatives can be used for SFN.

***Proposal 8: For SFN scheme (PDCCH DMRS is associated with two TCI states in all REGs/CCEs of the PDCCH), Alt 1-1 is considered.***

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| Company | Comments |
| DOCOMO | Support the proposal |
| MediaTek | Support the proposal |
| Huawei, Hisilicon | For SFN transmission, we think not only 1-1, but also Alt3 can support it. SFN transmission could be a special case in result of configuration/indication. For example, when the two candidates occurs on the same resource, the UE can assume SFN transmission. So we suggest the following change:  ***Proposal 8: For SFN scheme (PDCCH DMRS is associated with two TCI states in all REGs/CCEs of the PDCCH), Alt 1-1 and Alt 3 are considered.*** |
| Convida Wireless | Support the proposal |
| Nokia/NSB | Fine with the proposal . |
| Futurewei | Support the proposal |
| LG | Support the proposal |
| Lenovo/Motorola Mobility | Support the proposal |
| Apple | Support the FL proposal. We are not sure whether Alt3 proposed by HW can work. More clarification for Alt3 is needed with regard to UE blind detection behavior. |
| ZTE | We don’t think we should mention which Alt here. The following simple proposal is enough:  ***Proposal 8: Consider ~~For~~ SFN scheme (PDCCH DMRS is associated with two TCI states in all REGs/CCEs of the PDCCH)~~, Alt 1-1 is considered~~*** |
| Samsung | Support the proposal. |
| Sharp | Support the proposal |
| OPPO | Support |
| Xiaomi | Support the proposal |
| CATT | Support the proposal. |
| CMCC | Support the proposal |
| Fraunhofer IIS/HHI | Support ZTE’s revised proposal |
| Ericsson | Support the proposal |
| Huawei, HiSilicon 2 | @Apple, for Alt 3, when two CORESETs are configured to be overlapped, and when two linked PDCCH candidates are fully overlapped, the UE may assume that both TRP1 and TRP2 have transmitted the same bits of PDCCH on the overlapped candidates, and thus it’s the SFN scheme. Then the UE behavior can be clear.  Regarding the UE blind detection, as this has been supported in Rel-15, so the legacy blind detection behavior can still be reused. In fact, assuming the overlapped candidates as SFN, UE only need to decode one time for the two candidates, thus the number of blind detection is reduced. |

FL update:

The proposal is supported by vast majority of companies.

Regarding Huawei/Hisilicon’s comment, if Alt3 is used, not only we need to ensure that REs are completely overlapping (full RB overlapping of CORESETs and full monitoring occasion overlapping of SS sets), but also two CORESETs need to be configured with the same scrambling, which requires adding the corresponding restrictions and constraints. For CCE limit, UE needs to perform three channel estimation (use TRS1 only, use TRS2 only, use TRS1+TRS2). Given all these additional complexities and the fact that benefit is not clear, I suggest to not add Alt 3 for SFN.

Regarding ZTE’s comment, the main goal of the proposal is to narrow down the scope for SFN. With the suggested change, the proposal is not very meaningful. Note that SFN scheme is already listed as part of Proposal 2.

Hence, the proposal 8 is unchanged, and I suggest to agree to the proposal given the clear majority view and technical merits.

***Proposal 8: For SFN scheme (PDCCH DMRS is associated with two TCI states in all REGs/CCEs of the PDCCH), Alt 1-1 is considered.***

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| Company | Comments |
| MediaTek | Support |