**3GPP TSG-RAN WG1 Meeting #103-e R1-2009683**

**e-Meeting, October 26th – November 13th, 2020**

**Agenda item:** 8.1.2.1

**Source:** Moderator (Qualcomm)

**Title:** Summary of email discussions [103-e-NR-feMIMO-02] for mTRP PDCCH enhancements

**Document for:** Discussion/Decision

# **Introduction**

The Rel-17 WID for further enhancements on MIMO (FeMIMO) includes the following objective:

1. Enhancement on the support for multi-TRP deployment, targeting both FR1 and FR2:
   1. Identify and specify features to improve reliability and robustness for channels other than PDSCH (that is, PDCCH, PUSCH, and PUCCH) using multi-TRP and/or multi-panel, with Rel.16 reliability features as the baseline

This document focuses on PDCCH reliability part. The company proposals are summarized, and offline proposals drafted passed on company contributions.

# **Summary of Contributions and Offline Proposals**

Various options / alternatives / cases / multiplexing schemes have been agreed for further study in RAN1 #102-e (See Section 7). Given the specification impacts and further details, a good level of down-selection is required in this meeting in order to be able to start working on the details in the next meeting. In the following sub-section, a summary of company contributions is described, and offline proposals are drafted for the following aspects:

* Different Options
* Different Cases
* Different multiplexing schemes
* Different Alternatives and different combinations considering the above aspects

## **Options 1, 2, and 3**

Based on RAN1 #103e contributions shown in References (see also Section 5 for detailed proposals), the company preferences are summarized for options 1-3. Note that these options are for non-SFNed based PDCCH reliability enhancements.

* Option 1 (no repetition):
  + CATT, Apple, LG, Nokia/NSB (for FDM), Xiaomi, Spreadtrum (for FDM), Convida Wireless (for FDM), Qualcomm, Lenovo/Motorola Mobility (for FDM/SFN) , Sharp, InterDigital
* Option 2 (repetition):
  + FUTUREWEI, Huawei/HiSilicon, vivo, CATT, CMCC, Samsung, OPPO, Fraunhofer IIS/HHI, Nokia/NSB (for TDM), NEC, MediaTek, Intel, Xiaomi, Spreadtrum, NTT DOCOMO, Ericsson, Lenovo/Motorola Mobility, Sharp, InterDigital
* Option 3 (multi-chance):
  + vivo, ZTE, CATT, Samsung, LG, Fraunhofer IIS/HHI, Lenovo/MotM

With respect to performance evaluation results, the following is observed:

* The following companies observe that Option1 and Option 2 have similar performance given the same amount of resources w/ and w/o blockage: Apple, Intel, Qualcomm
* The following companies observe that Option2 performs better than Option1 at least in the presence of blockage: Huawei/HiSilicon, ZTE, Samsung, Ericsson
  + Where Option 2 and Option 3 have similar performance: ZTE
* The following companies observe that Option1/Option2 performs better than Option 3
  + When there is no blockage: Huawei/HiSilicon, ZTE, Fraunhofer, , NTT DOCOMO, Qualcomm
  + Even in the case of blockage: Fraunhofer, , Qualcomm (for AL=2)

With respect to specification impact, while the details depend on specific Alts/Cases/Schemes, the following is mentioned by different companies and can be considered as potential specification impacts that require further discussions:

|  |  |
| --- | --- |
| Option 1 | * Configuration / association related: TCI state activation for a CORESET, Association / configuration of REG bundles (for FDM) / OFDM symbols (for TDM) with TCI state * Procedural related: CCE-REG mapping (for FDM), precoding assumption (for TDM), implicit BFD resource for BFR, default beam when CORESET has 2 TCI states |
| Option 2 | In addition to impacts mentioned for option 3 below, the following potential specification impacts are mentioned:   * Procedural related: BD limits (inter and intra-slot and inter and intra-span may require different changes), overbooking (applicable to Alt 1-3 and 3), SFI indication in DCI format 2\_0, Interrupted transmission indication by DCI format 2\_1, Uplink cancelation indication by DCI format 2\_4 |
| Option 3 | * Configuration / association related: Depends on Alts 1-2/1-3/2/3, but similar changes and/or constraints are expected (e.g. TCI state should be associated to PDCCH candidates or SS sets for Alt 1-2/1-3, association between SS set and two CORESETs for Alt2, and constraints for Alt3). Also, the linkage between PDCCH candidates are required for Case 2. * Procedural related:   + HARQ-Ack related: DAI for Type-2 codebook, implicit PUCCH resource determination for >8 PUCCH resources in the resource set   + Timing related: Slot offset (applicable to inter-slot) for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, Reference for SLIV when “ReferenceofSLIV-ForDCIFormat1\_2”, scheduling offset for “timeDurationForQCL”, Interruption time for BWP switching, Out-of-order / in-order definition for PDCCH-to-PDSCH, and PDCCH-to-PUSCH, drx-InactivityTimer for DRX, Search space set group switching by DCI format 2\_0, TPC command in DCI formats 2\_2 and 2\_3   + Rate matching PDSCH around scheduling DCI resources   + CORESETPoolIndex related issues when used in a multi-DCI CC |

With respect to UE complexity, it is commonly understood by companies that Option 1 has smaller complexity compared to option 2.

Given the above preferences and discussions, it is not clear how to proceed. Option 2 has relatively more support but other Options are also supported by 7-8 companies. In terms of spec effort, Option 2 / 3 have much more impact. Option 1 has the smallest spec impact, but may result in some restrictions as mentioned by some companies (e.g. AL=1 with REG bundle size=6 for FDM, or 1-symbol CORESET for TDM cannot be supported). In terms of performance, observations are not the same among the companies who provided simulation results.

Based on above, in this meeting, the group can decide between Proposals 1-1, 1-2, and 1-3 below. Note that in the case of Proposal 1-2 / 1-3, we still need to have some progress on details of each option in this meeting. Also, note that SFN case is separately discussed in Section 2.3.

***Proposal 1: For non-SFN schemes, choose one of the following in RAN1 #103e***

* ***Proposal 1-1: At least support Option 2. Further study other options.***
* ***Proposal 1-2: Further evaluate and study the specification impact of different options, and down-select one option among options 1 and 2 in RAN1 #104e (i.e., option 3 is not considered further)***
  + ***Discuss some details of options 1 and 2 in this meeting in terms of the specification impact.***
* ***Proposal 1-3: Further evaluate and study the specification impact of different options, and down-select one option among options 1, 2 and 3 in RAN1 #104e.***
  + ***Discuss some details of each option in this meeting in terms of the specification impact.***

Please indicate your preference among Proposal 1-1, proposal 1-2, and Proposal 1-3. Also, please express your views in terms of specification impact and/or performance based on / in addition to the summary above to align understanding.

|  |  |
| --- | --- |
| Company | Comments |
| CATT | We support proposal 1-3.  Regarding downselection among the above three options, we think more discussions are needed in this meeting. From performance perspective, soft combining may result in higher reliability. However, selective decoding can also be used even with option 2. Therefore, it’s not appropriate to conclude that option 2 outperforms option 1 in all the cases.  Compared with option 1, independent decoding can still be achieved with option 3 in case one of the links is blocked. However, if there is no blockage or higher coding rate is used (e.g. AL=2), it’s expected that option 1 outperforms option 3.  In addition, as we didn’t show the performance comparison between option 1 and 3 in our contribution, we removed CATT from the following observation:  With respect to performance evaluation results, the following is observed:   * The following companies observe that Option1 and Option 2 have similar performance given the same amount of resources w/ and w/o blockage: Apple, Intel, Qualcomm * The following companies observe that Option2 performs better than Option1 at least in the presence of blockage: Huawei/HiSilicon, ZTE, Samsung, Ericsson * The following companies observe that Option1/Option2 performs better than Option 3   + When there is no blockage: Huawei/HiSilicon, ZTE, Fraunhofer, Intel, NTT DOCOMO, Qualcomm   + Even in the case of blockage: Fraunhofer, Intel, Qualcomm (for AL=2) |
| ZTE | Based on our tdoc, we update the above observation as follows in red.   * The following companies observe that Option2 performs better than Option1 at least in the presence of blockage: Huawei/HiSilicon, ZTE, Samsung, Ericsson   + Where Option 2 and Option 3 have similar performance: ZTE   We don’t understand why SFN should be discussed separately. In our view, option 1 including SFN(with two TCI states), TDM and FDM where they have the same functionality and UE complexity. Thus, support one of them is sufficient.  Further, based on the summary, the number of support companies is almost the same for option1 and option 3, we cannot accept the proposal 1-2 above.  In addition, flexibility is another important factor. Option 1 and 2 cannot support dynamic switching between single-TRP and multi-TRP PDCCH transmission while Option 3 is more flexible as we analyzed in our tdoc.  Thus our suggestion is  ***Proposal 1: Choose one of the following in RAN1 #103e***   * ***Proposal 1-1: At least support Option 2, further discuss other options.*** * ***Proposal 1-3: Further evaluate and study the specification impact , flexibility of different options, and down-select at least one option among options 1, 2 and 3 in RAN1 #104e.*** |
| MediaTek | Support proposal 1-1.  For option1 + alt 1-1, we have some issues for limited configuration like AL1 (FDM), 1 or 3 symbols (TDM) as FL mentioned. Moreover, it cannot support AL16+AL16 which provides more reliability. If we just use AL8+AL8 for blockage scenario for option 1 + alt 1-1, it will not be easy to suffice the BLER requirement for some URLLC use cases (BLER requirement for factory automation and power distribution is 10^-6). If we use option 2, the gNB can configure appropriate AL and multiple repetitions to satisfy the latency and BLER requirement flexibly depending on use cases. |
| NTT Docomo | We prefer proposal 1-1.  In terms of specification impact, we agree that HARQ related/timing related/rate matching/DCI format 2\_0/2\_1/2\_4 issues need to be further studied for option2. In our understanding, these issues are solvable with explicit linkage between two PDCCH candidates. |
| NEC | Support proposal 1-1.  And we share similar view as DoCoMo that explicit linkage between PDCCH candidates should be supported to solve related issues, and can also reduce UE complexibility. |
| Intel | For Option-1 we see some drawbacks:   * Cannot support AL16+AL16 or higher (similar comment as MTK) * Cannot support selection diversity decoding (that can be used for Option 2 or option 3) – similar comment as CATT * Additional work is needed to support dynamic switching between s-TRP and m-TRP PDCCH (similar comment as ZTE)   We think proposal 1-1 can be extended to include both option 2 and option 3 in this meeting. This is because of the following: We think s-TRP/m-TRP dynamic switching should be supported in option 2 as well. We also think that we should consider selection diversity receiver for option 2. Then option-2 and option-3 becomes very similar. (not sure everybody has same understanding of option-2, option-3 differences) |
| QC | Our main concern with Options 2 / 3 is the amount of specification impacts. Option 1 has the least specification impact and least UE complexity.  From performance point of view, we do not see much difference even in the case of blockage. In our view, it would be helpful to further align the simulation assumptions to ensure that all companies simulate the same scenario. As one example, companies simulated different blockage level and probabilities (x=7, 10, 20dB; p=10%, 100%).  Regarding restrictions for option 1, we have the following comments:   * For FDM with AL=1: The restriction is only for the case that REG bundle size=6. Network can configure other REG bundle size. Furthermore, in our understanding AL=1 is not the main scenario of interest. Even with Option 2 / 3, we do not have an equivalent to AL=1 in terms of resources. So, if anything, option 1 is more flexible (since 1 CCE DCI is possible with option 1, e.g., when REG bundle size is not 6, but it is not even possible with options 2 and 3) * For TDM with 1-symbol CORESET: Network can configure 2-symbol CORESET. Even with options 2 / 3, at least 2 symbols are needed overall for TDM by definition. Hence, we cannot view that as limitation of Option 1. * Regarding AL16+AL16: First, it is not fair to compare option 1 with AL=16 and options 2 and 3 with AL16+AL16. Second, AL16+AL16 is not related to reliability. It is related to the operation point, i.e., SINR regime. If there is an interest to extend the PDCCH coverage (i.e. min SINR operating point), the fair comparison is to compare AL16+AL16 (in options 2 / 3) with AL32 (in option 1).   For option 3, we think the performance is not close to Options 1 / 2 in most scenarios, and should not be furthered considered. Hence, our preference is Proposal 1-2. We cannot accept Proposal 1-1 without further discussions on the spec impacts, but we are ok with Proposal 1-3.  Also, one comment to ZTE: Options 1, 2, 3 are specifically defined for non-SFN schemes based on the agreement (they are not relevant for SFN). |
| Xiaomi | Support proposal 1-1 |
| Apple | Support Proposal 1-2 in principle. However we suggest we make a decision in this meeting. Several issues are connected with this proposal.  Option 2 can provide better performance only when soft combining is enabled, however soft combining may increase UE complexity for blind detection. So if we consider the trade-off between performance and UE complexity, option 1 is better than option 2.  Option 3 cannot work for all DCI formats with TPC command, and it results in the worst performance. |
| Huawei, HiSilicon | We have several comments on the FL’s proposal. Firstly, proposal 1-3 seems to be trivial compared to the agreement of last meeting. It’s not needed if further progress is targeted by the proposal, as anyway the three options will be studied. On proposal 1-2, to downselect between options, the aspects other than the specification impact should also be considered by interested companies, such as the performance which is more important on the usage of this feature.  Therefore, we propose to update the proposal as below:   * ***Proposal 1-1: Support Option 2.*** * ***Proposal 1-2: ~~Further evaluate and study the specification impact of different options, and~~ down-select one option among options 1 and 2 in RAN1 #104e (i.e., option 3 is not considered further)***   + ***~~Discuss some details of options 1 and 2 in this meeting in terms of the specification impact.~~*** * ***~~Proposal 1-3: Further evaluate and study the specification impact of different options, and down-select one option among options 1, 2 and 3 in RAN1 #104e.~~***   + ***~~Discuss some details of each option in this meeting in terms of the specification impact.~~***   We support proposal 1-1. As in performance point of view, it is within the schemes with best performances in both blockage and non-blockage cases.  For option 1, there are following problems from our understanding:   * The performance of option 1 is worse than option 2 in some cases. As we mentioned in our contribution R1-2007587, blockage effect on the same bits of the mother code would cancel the expected benefit from multi-TRP diversity. So performance depends heavily on the TCI mapping patterns, considering different CORESET configurations, e.g., interleaving or not, REG bundle size, #of REGs, interleaving size, AL and etc. * Spec impact related to channel estimation and demodulation details needs to be careuflly studied, e.g.   + how the UE perform channel estimation for wideband precoding, considering non-contiguous CCE/REG for each TRP, DMRS outside PDCCH candidates, etc.,   + the splitting of REG bundle in FDM/TDM domain for mapping to TCI states,   + channel estimation of each CCE when belonging to different candidates,   So in our view, the spec impact for Option 1 seems to be huge.  Note that option 3 is just one UE implementation of option 2 from our understanding, and they are of the same specification framework. This is because linkage is also needed for option 3, considering that there should be a clear speficiation of UE behavior/timing related to Type II HARQ-ACK codebook, PUCCH resource determination, PDSCH processing time, TPC command etc, which may be common for option 2 and 3. |
| Lenovo/  Motorola Mobility | We prefer proposal 1-3 among listed proposals.  The selection can be discussed together with multiplexing scheme, CORESET and search space set configuration and candidate linkage relation information. Also, one or more options may be selected on account of their individual application scenario and benefit. |
| OPPO | Support proposal 1-1  Option 1:   * As many companies commented, there are many unnecessary restrictions introduced by Option 1, especially not support AL16+AL16. Thus, the flexibility of the NW and the robustness will be reduced if Option 1 is used. * Regarding the UE complexity, it depends on UE implementation/specification. Option 1 and Option 2 can have similar UE complexity by proper design/implementation * As for specification efforts, it also depends on the detailed design.   Option 3   * Compared Option 3, Option 1 and Option 2 can have less blind decoding by proper design * It prevents UE from joint reception of multiple PDCCH occasion, thereby leading to some performance gain |
| Nokia/NSB | We are supportive of option 2. We think supporting option 1 is alone will not be enough due to the reasons that several companies mentioned above. However, we are open to discuss option 1 to see the additional benefit that provides in addition to option 2. For this meeting, we could go with   * ***Proposal 1-1: Support Option 2. Further evaluate and study the support of option 2.*** |
| Fujitsu | Support proposal 1-1.  We prefer option 2. Also, we agree with the specification impact identified by FL. |
| Fraunhofer | The restrictions posed by option 1 in terms of AL and REG bundle sizes supported increase the specification effort. Support option 2/option 3 with an FFS for option 1. |
| Samsung | We cannot see the reason why the range of down-selection is different for each proposal 1-1 ~ 1-3. In that sense, ZTE’s revised proposal 1 seems better, although we think that proposal 1-1 and 1-3 seems a bit overlapped. We suggest the following modification would be needed to differentiate proposal 1-1 and 1-3.  ***Proposal 1: Choose one of the following in RAN1 #103e***   * ***Proposal 1-1: support Option 2 as a baseline, further discuss other options.*** * ***Proposal 1-3: Further evaluate and study the specification impact , flexibility of different options, and down-select more than one options among options 1, 2 and 3 in RAN1 #104e.*** |
| CMCC | Support proposal 1-1.  For BD limits, if explicit linkage is considered between two PDCCH candidates for option 2, UE will receive the CCEs of these two PDCCH candidates together, which can be assumed as one BD, so option 2 has no extra spec impact on BD limits with explicit linkage between two PDCCH candidates.  For SFI indication in DCI format 2\_0, Interrupted transmission indication by DCI format 2\_1, and Uplink cancelation indication by DCI format 2\_4, if explicit linkage is considered between two PDCCH candidates for option 2, one possible way is that the second PDCCH candidate can be used to determine the application timing of these fields. |
| vivo | We support proposal 1-3.  To avoid redundant design of enhanced PDCCH, down selection between Option1 and SFN to be done in this meeting. Although proposal1 is for non-SFN schemes, discussion on Option1, not only compare against option2 and option3, should also be considered together with SFN scheme in proposal3.  According to our evaluation results of SFN and Option1, and comparing pros and cons，for the progress Option 1 should be precluded.  In option2, performance of PDCCH repetition can be enhanced by soft bits combining at UE.  In option3, it not necessary to explicitly define linkage to avoid defining complicated rules and configurations.  Hence we only support option2 and option3. |
| Spreadtrum | Support proposal 1-2 in principle at current stage.  For option 3, if comparing with option 2, there is no combing gain; and if combing with option 1, the coding gain is limited. Thus, from the perspective of performance, we prefer not to support option 3. Regarding to spec impact for option 1/2/3, we agree with FL’s summary. |
| Ericsson | Our first preference is Proposal 1-1 from FL, but we are also ok with the following revised proposal from other companies:  ***Revised Proposal 1-1: Support Option 2. Further evaluate and study the support of option 1.***  We suggest not to go with proposal 1-3 as there is no progress if we go with this proposal. With option 3, without an explicit linkage between two PDCCHs scheduling the same PDSCH/PUSCH, different time offsets may be determined depending on which PDCCH is decoded successfully, and different UE actions may need to be taken which is a fundamental issue. But if explicit linkage is introduced between the two PDCCHs, then option 3 does not seem to have much benefit over option 2. So, we strongly prefer not to further discuss option 3. |
| Convida Wireless | We suggest supporting both Option 1 (for FDM) and Option 2 (for TDM).   * Option 1 with TDM introduces different TCI states in a REG bundle, with significatn impact on channel estimation. Therefore, we support Option 1 only for FDM.   Option 2 with TDM can support intra- and inter-slot repetition. |
| Futurewei | Support Proposal 1-1.  Though we did not directly simulate Option 1, the performance of Option 1 should be between S-TRP scheme and soft combining/UE selection schemes with 5%/10% blockage, and hence we can indirectly conclude that Option 2 outperforms Option 1. |
| Sharp | We support option 1-1. As some companies proposed, further evaluation and study of option 2 are OK. |
| LG | Our first preference is option 3 but based on evaluation results from other companies we are fine to support option 2 and leave FFS on option 3. Regarding option 1, most companies show option 2 achieves equal or better performance that option 1. So performance wise, it is not reasonable to introduce option 1 in addition to option 2. If some company have concern on UE implementation burden for option 2, we can consider SFN based enhancement providing 3dB power boosting in non-blockage scenario and diversity gain in blockage scenario. |
| InterDigital | Our preference is option 1-2, however we could also support 1-1. |

## **Cases 1 and 2 for Options 2/3**

For Options 2 / 3 (repetition / multi-chance), two cases were agreed for further study. Based on RAN1 #103e contributions, the company preferences are summarized for Cases 1 / 2:

* Case 1 (Two or more PDCCH candidates are explicitly linked):
  + FUTUREWEI, Huawei/HiSilicon, vivo, Fujitsu, CATT, CMCC, Samsung (for option 2), OPPO, Fraunhofer IIS/HHI, Nokia/NSB, NEC, MediaTek, Intel, Spreadtrum, Convida Wireless, NTT DOCOMO, Ericsson, Xiaomi, Lenovo/Motorola Mobility, InterDigital
* Case 2 (Two or more PDCCH candidates are not explicitly linked):
  + vivo, ZTE, Samsung (for option 3) , Lenovo/Motorola Mobility

Case 1 has a clear majority support. It is commonly understood that Case 2 is only applicable to Option 3 (multi-chance) and is not applicable to Option 2 (repetition). Otherwise, Option 2 becomes the same as Option 3 from UE / specification point of view. On the other hand, Case 1 is applicable to both Option 2 and Option 3. Furthermore, it is mentioned by multiple companies (e.g. OPPO, Apple, NEC, Ericsson, Qualcomm) that Case 2 results in ambiguity between UE and gNB and scheduling restrictions. For Case 1, different linking options are proposed by different companies such as a fixed rule based on the same PDCCH candidate index, based on start CCE, or based on configuration. Further details also depend on different Alts.

***Proposal 2: If Option 2 or 3 is agreed, only Case 1 (explicit linking) is supported.***

|  |  |
| --- | --- |
| Company | Comments |
| CATT | We think this proposal is related to subsection 2.4, and the linkage issue can be discussed together with different alternatives of combination. Furthermore, for the discussion on linkage issue, option 1(no repetition) should also be considered.  For example, if one PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET, explicit linking is not needed for option 1. |
| ZTE | Disagree this proposal.  If Option 2 is agreed, we admit that Case 1 is natural to be supported. However, if option 3 is agreed, the benefit of combined with case 1 is unclear. Once explicit link is configured, gNB cannot schedule independent data by two linked PDCCH candidates anymore, this restriction causes more PDCCH overhead, and less flexibility if the maximum number of BD, CCE is the same as Rel-16. The available PDCCH candidates will be reduced to half compared with Rel-16.  Regarding the issues companies raised for Case 2, we don’t think they are critical and unsolvable. For example, for the scheduling timing issues, one solution is to introduce an additional time offset for one of two DCIs. Regarding common group DCI, we don’t think the MTRP solution is applicable for it. That’s because common group DCI is for multiple UEs, however, different UEs may have different coordinated TRPs, the second TCI is hard to be shared for the multiple coordinated TRPs of different UEs.  Thus, our suggestion is  ***If Option 2 is agreed, support option 2 combined with case 1. If Option 3 is agreed, support opton 3 combined with case 2.*** |
| MediaTek | Support proposal 2. |
| NTT Docomo | We support FL’s proposal. |
| NEC | Support the proposal, and we support option 2 combined with case 1. |
| Intel | we believe explicit linking is beneficial for soft-combining candidates (not all candidates). However, as ZTE has mentioned we also see the need for s-TRP/m-TRP dynamic switching and Option-2/Option-3 should support that. We can say something like explicit linking is supported for soft-combining candidates. |
| QC | Support. Certain issues are not easily solvable for Case 2. In our contribution, we listed some of those issues. As just one example, it becomes unclear how out-of-order scheduling can be defined for Case 2.    As another example, it is unclear how PDSCH rate matching around the scheduling DCI can be done. There are a number of other similar issues that we see for Case 2. |
| Xiaomi | Support the proposal |
| Apple | Do not support the proposal. We can only start the work for option 2, when it is agreed as at least a working assumption. |
| Huawei, HiSilicon | Support in principle.  However, it’s preferable to make a decision on proposal 1 before discussion on proposal 2. |
| Lenovo/  Motorola Mobility | Support both case 1 and case 2. For case 2, we think the flexibility of PDCCH resource allocation and blocking performance are better. |
| OPPO | Support FL’s proposal |
| Nokia/NSB | Support the proposal. |
| Fujitsu | Support FL’s proposal. |
| Fraunhofer | Support FL’s proposal. |
| Samsung | Not support proposal 2 and agree with ZTE’s modified proposal. We think that there are proper combinations among options and cases which are inter-related, not an independent factor. In that sense, option 2 with case 1 seems natural to reduce UE’s blind decoding complexity. However, regarding option 3, case 2 seems reasonable since that combination can make PDCCH repetition scheme with the least specification impact. |
| CMCC | Support FL’s proposal.  For Option 2, explicitly linkage (case 1) is beneficial for soft-combining and has less spec impact on some cases, such as timing definition. If other companies have concern on Option 3 with case 1, at least if Option 2 is agreed, only Case 1 (explicit linking) is supported. |
| vivo | Do not agree the proposal. Implicit linkage should also be supported. To support implicit linkage, spec enhancement is needed to avoid ambiguity when UE detects M-DCI. For simplicity, it can be considered to limit, for example, for DCI in USS. Implicitly linked M-DCI can flexibly support dynamic switching between S-TRP and M-TRP.  Regarding the issue of scheduling timeline, the combination of multi-chance and Alt3 can support 2 CORESETs which are associated with different CORESET pool indices as in NCJT transmission. If 2 DCI schedule same HARQ ID then UE can determine same TB being scheduled. |
| Spreadtrum | Support FL’s proposal. |
| Ericsson | Support FL’s proposal. But we think it is better to add the following clarification note to Case 1.  “Note: for Case 1, different linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, or based on configuration can be further studied.” |
| Convida Wireless | Support the FL proposal. |
| Futurewei | Support the FL’s proposal.  Explicit linkage (Case 1) is able to support soft combining scheme, UE selection scheme (such as when one PDCCH candidate has a low SNR due to, e.g., blockage), gNB selection (e.g., one TRP is not transmitting a PDCCH candidate but the UE treats it the same way as being blocked), and hence dynamic switching of TRP1/TRP2 and dynamic switching of M-TRP/S-TRP.  Case 2 has several issues as described above and in our contribution. For example, assume that the UE needs to combine (e.g., using chase combining) two PDCCH candidates to successfully decode the PDCCH, that is, either PDCCH candidate does not have sufficient SINR to be decoded alone. Without a known linkage, the UE has to try to combine any candidate from the first TRP with any candidate from the second TRP. If there are n candidates for either TRP, this leads to n2 combinations that the UE has to try, which is practically feasible only if n is small. However, limiting n to be a small number can degrade the performance. Hence, we suggest to consider explicit linkage only. |
| Sharp | Support FL’s proposal |
| LG | We have similar view with ZTE and Samsung. Explicit linkage is not necessary for Option 3 and following up issue such as timing determination can be further studied. |
| InterDigital | Support FL’s proposal |

## **Multiplexing Schemes**

Three multiplexing schemes were agreed for further study. Based on RAN1 #103e contributions, the company preferences are summarized below:

* TDM:
  + FUTUREWEI, Huawei/HiSilicon, vivo, ZTE, Fujitsu, CATT, CMCC, Samsung, OPPO (higher priority), LG (high priority), Nokia/NSB, Lenovo/MotM (as baseline), MediaTek, Intel, Spreadtrum, Convida Wireless, NTT DOCOMO, Ericsson, Qualcomm, Xiaomi, Sharp, InterDigital
* FDM:
  + FUTUREWEI, Huawei/HiSilicon, Fujitsu, CATT, CMCC, OPPO, LG, Fraunhofer IIS/HHI, Nokia/NSB, Lenovo/MotM, Intel, Spreadtrum, Convida Wireless, NTT DOCOMO, Ericsson, Qualcomm, Xiaomi, Sharp, InterDigital
* SFN:
  + FUTUREWEI, vivo, ZTE, CATT, CMCC, OPPO, LG, Lenovo/MotM, NTT DOCOMO, Xiaomi

With respect to performance evaluation results, the following is observed:

* The following companies observe that FDM (or TDM) performs better than SFN: Huawei/HiSilicon,
* The following companies observe that SFN performs similar to FDM (or TDM): Vivo, ZTE, Fraunhofer (with a note that in practice, this may not be the case), Futurewei (for cases with 0 us M-TRP signal arrival time differences, 0%/5%/10% blockage, and 1 FFT, with BLER 1E-4 ~ 1E-3; for cases with 0.5/1/2 us M-TRP signal arrival time differences, 0% blockage, and 2 FFT for non-SFN)
* The following companies observe that SFN performs better than FDM in some scenarios: ZTE, Futurewei (for cases with 0.5/1/2 us M-TRP signal arrival time differences, 0% blockage, and 1 FFT)

As mentioned by multiple companies, TDM should be supported as it is required for UE with one panel in FR2. The benefit of FDM and SFN is lower latency, but they require multi-panel capability in FR2. Furthermore, transparent SFN is already possible at least for FR1.

***Proposal 3: Choose one of the following in RAN1 #103e***

* ***Proposal 3-1: Support both TDM and FDM schemes. Further study SFN scheme.***
* ***Proposal 3-2: Support TDM, FDM, and SFN.***
* ***Proposal 3-3: Support TDM scheme. Down-select at least one scheme between FDM and SFN in RAN1 #104e.***

Please indicate your preference among Proposal 3-1, proposal 3-2, and proposal 3-3. Also, please indicate which one is not acceptable to you.

|  |  |
| --- | --- |
| Company | Comments |
| CATT | As summarized by FL, each scheme has its pros and cons, and then different scheme can be applied in different scenarios for UEs with different capabilities. Therefore, proposal3-2 is preferred, and proposal 3-3 is not acceptable to us. |
| ZTE | We update the observation above based on ZTE’s tdoc.  It is hard to discuss this proposal without combining any specific Options/Cases. For example, if we agree FDM, does this mean option 1+FDM or option 2 + FDM or option 3+ FDM ?  We prefer to discuss this with specific options together. |
| MediaTek | Suggest to add one more proposal. For latency issue of TDM, we could just use two OFDM symbols (each per TRP) with intra-slot repetition. We don’t see the necessity of FDM. For SFN, this can be discussed in 8.1.2.4 (HST/SFN).   * ***Proposal 3-4: Support TDM scheme. Further study FDM and SFN scheme.***   Proposal 3-2 is not acceptable to us. |
| NTT Docomo | We prefer proposal 3-2. |
| NEC | Proposal 3-2 is preferred. |
| Intel | Not sure if a specific agreement is needed here. We think multiplexing is already covered as part of CORESET and SS-set definition from Rel-15 and we can directly focus on 2.4 |
| QC | SFN scheme can be discussed in 8.1.2.4 as mentioned by MediaTek. We prefer Proposal 3-1, but we can also accept Proposal 3-2 if we decide to discuss SFN in this sub-agenda.  One comment to MediaTek: Even with intra-slot repetition / TDMed option 1, at least 2 symbols are required. FDM can reduce the latency further. |
| Xiaomi | We prefer proposal 3-2 |
| Apple | Support Proposal 3-2 |
| Huawei, HiSilicon | Support proposal 3-1 in principle. FDM is an important case especially for URLLC to maintain low latency. SFN related scheme can also be considered if time permits.  However, it’s preferable to make a decision on proposal 1 before discussion, so that we have a clear picture on support of multiplexing schemes. |
| Lenovo/  Motorola Mobility | We prefer proposal 3-2 |
| OPPO | We prefer Proposal 3-1. The performance of SDM needs further investigation due the interference between different TRPs |
| Nokia/NSB | Support proposal 3-3. TDM seems supported by all companies.  *Proposal 3-3: Support TDM scheme. Down-select at least one scheme between FDM and SFN in RAN1 #104e.* |
| Fujitsu | We prefer proposal 3-1. |
| Fraunhofer | Support proposal 3-1 |
| Samsung | Not support the FL proposal. Based on the previous agreement, SFN scheme should be related and have dependency with AI 2d (HST-SFN). Hence, on support of SFN, it seems reasonable to follow the outcome of AI 2d rather than discussing in here. Instead we suggest to focus on down-selecting between TDM and FDM in here. |
| CMCC | Support proposal 3-2.  We agree with CATT that each scheme has its pros and cons, and then different scheme can be applied in different scenarios for UEs with different capabilities. For example, compared with TDM scheme, FDM scheme is benefit for the low latency, then FDM scheme could be supported for UEs with higher capability that can receive two beam simultaneously. Besides, SFN is a typical scheme for HST, which should be also enhanced for this scenario. |
| vivo | In our view, proposal 3 should be discussed first, down selection can be done based on available evaluation results. Once down selection of one or more schemes is done, the combinations of alternatives and options will automatically shrink. Currently, SFN scheme is clear and should be supported in order to support SFN based HST, from design and benefit point of view TDM and FDM schemes are not so clear at the moment. Hence we propose:  ***Proposal 3-4: Support SFN, TDM***   * ***support TDM based on multi-repetition or multi-chances，***   ***TDM based on symbol of CORESET should be precluded.***   * ***further study the pros of FDM comparing with SFN or TDM*** * ***FFS: whether Combination SFN and TDM is supported or not.***   We support SFN only against Option1 TDM(symbol level) and Option1 FDM(REG bundle level) due following reasons:   1. SFN is suitable for HST whereas option1 TDM and FDM cannot support efficiently 2. Performance of SFN (with small delay CDD between 2 TRPs) is similar to FDM joint encoding and FDM separate encoding (Ref R1-2005364 in #102e) 3. SFN and FDM have same latency 4. SFN can be supported 1 COREST with two active TCI states, whereas complicated design FDM/TDM with regard to TCI state association and REG bundle/symbol 5. TDM in symbol granularity doesn’t support 1 symbol CORESET and is not straight forward with 3 symbols CORESET. There are no evaluations results showing benefits. |
| Spreadtrum | Support proposal 3-3. It seems that TDM is ok for all companies. More discussions on FDM and SFN are needed. |
| Ericsson | We support Proposal 3-1. |
| Convida Wireless | Support proposal 3-1. |
| Futurewei | We support at least TDM. As we suggested in our contribution, TDM works well for FR1 and FR2, but for FR2, it may be challenging to support FDM/SFN for PDCCH. So we suggest to include FR1/FR2 distinctions in the proposal, e.g.:  ***For FR1, at least TDM is supported. Further study FDM/SFN.***  ***For FR2, support TDM.*** |
| Sharp | Support proposal 3-1 |
| LG | There seems no concern on TDM so we can agree TDM first. Regarding SFN, in my understanding, if PDSCH SFN enhancement is introduced it is quite natural to extend it to PDCCH as well. So, we prefer to support SFN PDCCH as well. |
| InterDigital | Support proposal 3-1 |

## **Alternatives and different combinations**

To enable a PDCCH transmission with two TCI states, different Alts have been agreed in RAN1 #102e. Based on RAN1 #103e contributions, the company preferences are summarized below:

* Alt 1-1 (one CORESET with 2 TCI states; one PDCCH candidate):
  + Vivo (for SFN and SFN+TDM), CATT, OPPO, Apple, LG, Nokia/NSB (for FDM), Xiaomi, Spreadtrum, Convida Wireless (for FDM), Qualcomm, Lenovo/Motorola Mobility
* Alt 1-2 (one CORESET with 2 TCI states; two or more PDCCH candidates in the same SS set):
  + CATT, Nokia/NSB (for TDM), MediaTek (second preference if multiple monitoring occasions)
* Alt 1-3 (one CORESET with 2 TCI states; two or more PDCCH candidates in different SS sets):
  + Huawei/HiSilicon, Vivo, TCL comm., CATT, CMCC, MediaTek (second preference if multiple monitoring occasions), Xiaomi, NTT DOCOMO
* Alt 2 (one SS set associated with 2 different CORESETs):
  + CATT, Sony, Fraunhofer IIS/HHI, Ericsson
* Alt 3 (two SS sets associated with corresponding CORESETs):
  + FUTUREWEI, Huawei/HiSilicon, ZTE (for option 3), CATT, CMCC, Samsung, Sony, Fraunhofer IIS/HHI, Nokia/NSB (for TDM), MediaTek (first preference), Intel, Xiaomi, Spreadtrum, Convida Wireless (for TDM), NTT DOCOMO, Ericsson, Lenovo/Motorola Mobility

Decision on the alternatives depends on the decision on Options (1/2/3) and to some extend on the decision on multiplexing schemes. The following combinations have been considered by companies as valid / reasonable:

* Combination A: Alt 1-1 combined with Option 1 (for TDM / FDM) and/or combined with SFN
* Combination B: Alt 1-2/1-3/2/3 combined with Option 2 / Option 3 (for TDM / FDM)

***Proposal 4-1: For PDCCH reliability enhancements, only the following combinations are further considered:***

* ***Combination A: Alt 1-1 combined with Option 1 (for TDM / FDM) and/or combined with SFN***
* ***Combination B: Alts 1-2/1-3/2/3 combined with Option 2 / Option 3 (for TDM / FDM)***

|  |  |
| --- | --- |
| Company | Comments |
| CATT | Support this proposal. |
| ZTE | This proposal should be first discussed since it can help us narrow down the scope. We are OK for this proposal. |
| MediaTek | This can be discussed after we agree on proposal 1. |
| NTT Docomo | We support FL’s proposal. |
| NEC | Support the proposal. |
| Intel | Generally looks a reasonable way for down-selection. However, we have the following comments for combination B that we should clarify:   * Its not clear how Alt-1-3 supports FDM. It seems that the candidates for both SS-sets are exactly overlapping (in frequency) so the candidates should be strictly TDM for soft-combining.   For Alt-1-2, different monitoring occasions seems to be the only reasonable option |
| QC | Support |
| Xiaomi | Support the proposal |
| Apple | Support combination A only. |
| Huawei, HiSilicon | From our understanding, the SFN is independent from the three options, the proposal 4-1 should only focus on non-SFN transmission, so the following is proposed:  ***Proposal 4-1: For PDCCH reliability enhancements with non-SFN transmission, only the following combinations are further considered:***   * ***Combination A: Alt 1-1 combined with Option 1 ~~(for TDM / FDM)~~ ~~and/or combined with SFN~~*** * ***Combination B: Alts 1-2/1-3/2/3 combined with Option 2 / Option 3 ~~(for TDM / FDM)~~***   In fact, the SFN is very clear to companies, there’s no need to combine SFN with any alternatives. The spec impact of SFN can be discussed independently if it’s agreed to be supported. |
| Lenovo/  Motorola Mobility | We generally support FL’s proposal. For combination A, it can be further discussed/considered whether TDM can be supported. |
| OPPO | One clarification on PDCCH candidate: if a PDCCH repetition is defined by a fixed offset (e.g., time-domain, frequency-domain offset), and UE will receive them only by soft-combination, is it one PDCCH candidate, or multiple PDCCH candidates? From our understanding, it should be only one 1 PDCCH candidate in this case. Thus, we think combination B should also include Alt 1-1  ***Combination B: Alts 1-1/1-2/1-3/2/3 combined with Option 2 / Option 3 (for TDM / FDM)*** |
| Nokia/NSB | Not fully clear how to proceed here (as some aspects are related to earlier proposals).  In general, we are fine with further studying other approaches (Combination A) if something is not agreeing in the earlier proposals. |
| Fujitsu | Support the proposal. |
| Fraunhofer | Support the mentioned combinations for discussion in principle. However, the scope of this proposal seems to be quite broad. It also covers multiplexing schemes, which are also discussed in proposal 3. |
| Samsung | Support this proposal. |
| CMCC | Support FL’s proposal. |
| vivo | * For Combination A，if SFN is supported then Alt 1-1 combined with Option 1 (for TDM / FDM) should not supported. As we explained above, Alt 1-1 combined with Option 1 (for TDM / FDM) has no benefit compared to SFN * For Combination B, it can observed that Alt1-2 and Alt2 have fewer support, should be down selected。 * ***We propose following revision of combinations A and B, and add Combination C*** * ***Combination A: Alt 1-1 combined with Option 1 (for TDM / FDM) ~~and/or combined with SFN~~*** * ***Combination B: Alts ~~1-2/~~1-3~~/2~~/3 combined with Option 2 / Option 3 (for TDM / FDM)*** * ***Combination C: Alt 1-1 combined with SFN, Alt 1-3 combined with Option2, Alt 3 combined with Option3*** |
| Spreadtrum | Support FL’s proposal |
| Ericsson | For Alt 1-1 combined with Option, we think it makes sense for SFN. So, we suggest the following revision:  ***Proposal 4-1: For PDCCH reliability enhancements, only the following combinations are further considered:***   * ***Combination A: Alt 1-1 combined with Option 1 ~~(for TDM / FDM) and/or combined with~~ for SFN*** * ***Combination B: Alts 1-2/1-3/2/3 combined with Option 2 / Option 3 (for TDM / FDM)*** |
| Convida Wireless | Support FL’s proposal. |
| Futurewei | Support Huawei’s revision and/or Ericsson’s revision. Note that Option1/2/3 as agreed previously are for non-SFN and thus it is better to clarify. |
| Sharp | Support FL’s proposal |
| InterDigital | Support FL’s proposal |

For Combination B, one alternative among Alts 1-2/1-3/2/3 should be supported. Among these, Alt 3 has the majority support. It is preferred to down-select to one alternative so that further discussions become more focused. Furthermore, some of the companies that prefer a different alternative acknowledge that all Alts achieve the same functionality and have more or less similar specification impact.

***Proposal 4-2: If Option 2 or 3 is agreed, Alt 3 (Two SS sets associated with corresponding CORESETs) is supported.***

|  |  |
| --- | --- |
| Company | Comments |
| CATT | Further discussion is needed for combination B in this meeting. In our view:   * In Alt.1-2, two sets of PDCCH candidates (in a given SS set) are associated with the two TCI states of the CORESET, respectively. Since this alternative relates to more than one PDCCH candidates, it can be combined with Option 2 or Option 3 to perform PDCCH repetition or multi-chance transmission. With these combinations, multiple DCIs are transmitted within a SS set (e.g., a SS set assigned for PDCCH reliability transmission) and the range of blind detection or blind combination is also limited to this SS set, which is helpful to reduce complexity of blind detection. * For the combination of Alt.1-3 and option 2/3, multiple DCIs are transmitted within a CORESET (e.g., a CORESET assigned for PDCCH reliability transmission) and the range of blind detection or blind combination is also limited to this CORESET, which will not affect the transmission of other PDCCHs (e.g., PDCCH without reliability enhancements) or other CORESETs. * For the combination of Alt.2 and option 2/3, similar to the combination of Alt.1-2 and Option 2/3, multiple DCIs are transmitted within a SS set, which is helpful to reduce complexity of blind detection. The difference between this combination and the combination of Alt.1-2 and Option 2/3 is that different enhancements are needed to achieve the same function. The former needs to enhance the association between PDCCH candidate and TCI state, while the latter needs to enhance the association between PDCCH candidate and CORESET. * For the combination of Alt.3 and option *2/3*, TCI framework of CORESET in R15 can be reused, and the association between SS set and CORESET in R15 can also be reused. However, multiple DCIs can be transmitted in all possible (monitored) SS sets or CORESETs, which makes explicit linkage between two PDCCH candidates necessary. |
| ZTE | This proposal should be first discussed since it can help us narrow down the scope. We are OK for this proposal. |
| MediaTek | Support proposal 4-2  Alt 3 have the several advantages such as the support of flexible TDM transmission, the additional reliability with soft combining, implicit per-TRP BFR, and more than 2 repetitions. In addition, we don’t need to introduce two TCI states compared with Alt 1 and don’t need to map two TCI states/CORESETs to each monitoring occasion or each SS set unlike other alternatives. We only need to associate two SS sets. Furthermore, each SS set/CORESET can be separately used for S-TRP by introducing the activation/deactivation of association. We believe that Alt 3 can be the best candidate considering the performance and flexible configuration. |
| NTT Docomo | We support FL’s proposal. |
| NEC | Support the proposal. |
| Intel | Seems reasonable to us |
| QC | Support. For option 2, our understanding is that in terms of blind decoding / complexity (and many other spec impacts), all Alts among 1-2 / 1-3 / 2 / 3 are similar. Alt 3 is more natural for options 2 / 3, and does not require some of the additional association / configuration enhancements (other than linkage in Case 1 which is common to all Alts for options 2 and 3). |
| Xiaomi | Support the proposal |
| Apple | Do not support the proposal. We can only start the work for option 2/3, when it is agreed as at least a working assumption. |
| Huawei, HiSilicon | Support the proposal 4-2 in principle. It’s preferable to make a decision on proposal 1 before discussion. |
| Lenovo/  Motorola Mobility | We support Alt.3 has the highest priority if option 2 or option 3 is agreed. Other Alternatives can be further discussed. |
| OPPO | Further discussions are needed. The pros/cons of each alternative depend on the detailed solutions. |
| Nokia/NSB | Alt.3 has very restrictive use as always two CORESETs are used for PDCCH repetition, and additional restrictions on CORESET parameters may be needed. We are supportive of Alt 1-2 which seems to be providing much better flexibility when supporting option 2. |
| Fujitsu | Support the proposal. |
| Fraunhofer | Support the proposal. |
| Samsung | Support this proposal. We think that Alt 3 has the least specification impact upon the others. It is suitable for especially Option 3 since no explicit linkage is necessary for multi-chance which means that UE doesn’t need to know whether PDCCH is configured to support multi-chance or not. |
| CMCC | Do not support the proposal. Since only three CORESETs are supported for UE, to consider the CORESET configuration flexibility, Alt 1-3 occupies less CORESET than Alt 3, but Alt 1-3 needs additional spec enhancement to support two TCI states for one CORESET. From our perspective, Alt 1-3 and Alt 3 could be both supported for Option 2. |
| vivo | Do not support  In Alt1-3, where 1 CORESET with 2 TCI states indicates enhanced PDCCH configuration, can be configured with linkage between candidate or monitoring occasion. In our view, Alt1-3 is suitable for explicitly linkage.  If combination explicit linkage with Alt1-3 is supported, then supporting combination of explicit linkage and Alt3 is redundant. Alt3 can reuse legacy design, without introducing new rules for linkage. With implicit linkage for Alt3, legacy configuration can be used and there is no change in UE decoding.  We propose:  ***Proposal 4-2: If Option ~~2 or~~ 3 is agreed, Alt 3 (Two SS sets associated with corresponding CORESETs) is supported.*** |
| Spreadtrum | Support FL’s proposal. |
| Ericsson | Since the proposal depends on whether option 2 or 3 is agreed, it is better to discuss this proposal after agreeing on the option(s) first. |
| Convida Wireless | Support FL’s proposal. |
| Futurewei | Support the FL’s proposal. |
| Sharp | Support FL’s proposal |
| InterDigital | Support FL’s proposal |

## **Updated Proposal**

FL summary: For Proposals 1/2/3/4 in the above, there does not seem to be consensus yet on any of the proposals. This is mainly due to dependency of Options / Alts / Cases / multiplexing schemes. Hence, I would like to suggest the following proposal to list clearly the combinations that make sense (revised proposal 1 is a mixture of the above proposals without too much down-selection). If this proposal is agreed, the next step is to discuss some of the concerns mentioned by companies for each Combination in more details in this meeting.

***Revised Proposal 1: For PDCCH reliability enhancements, only the following combinations are further considered:***

* ***Combination A: SFN scheme + Alt 1-1***
* ***Combination B: FDM / TDM schemes + Alt 1-1 + Option 1***
* ***Combination C: FDM / TDM schemes + Alts 1-2 / 1-3 / 2 / 3 + Option 2 / Option 3 + Case 1***
* ***Combination D: FDM / TDM schemes + Alt 3 + Option 3 + Case 2***

|  |  |
| --- | --- |
| Company | Comments |
| LG | We support combination A. If PDSCH SFN enhancement is introduced it is quite natural to extend it to PDCCH as well and Alt 1-1 is the only option for SFN scheme. For the other combination, there seems no objection to support TDM so we can make an agreement on TDM at least. |
| InterDigital | Do not support, as this is still a large set of options to work with. |
| MediaTek | We are also concerned if we only agree this at this meeting. It is huge combinations. We support combination C. Are we going to consider just one or multiple combinations? |

# **Round 2 Discussions**

It is clear that some down-selection is required in this meeting for progress. Based on the discussions during GTW session, a common understanding for some definitions is required as follows:

* Clarification 1: Options 1 / 2 / 3 are for non-SFN schemes (i.e. relevant only for TDM / FDM schemes) based on the agreement in RAN1 #102-e.
* Clarification 2: Alt 1-1 + SFN means that the DMRS port of each PDCCH candidate is associated with both TCI states of the CORESET.
* Clarification 3: Selection diversity versus soft-combining for non-SFN schemes
  + For selection diversity only (no soft combining), Option 3 + Case 1 (explicit linkage) or Option 3 + Case 2 (no explicit linkage) are valid combinations.
  + For soft-combining, only option 2 + Case 1 is a valid combination
  + Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?
  + Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?
  + It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed).

Please comment if the above is not your understanding, or if you would like to clarify the answer to the questions above.

|  |  |
| --- | --- |
| Company | Comments |
| Intel | *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  We think that supporting both soft-combining and UE selection is beneficial to support various UE complexities at the UE feature stage. Therefore if down-selection of Option 3 means that Option 2 mandates soft-combining UE reception it is not desirable for us. So we want to clarify that Option 2 may be supported by UE selection receiver as well.  *Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?*  We don’t see the connection between “network selection” and Option 3. To us NW selection means that the NW has the ability to dynamically choose a single AL16 PDCCH transmission from TRP-1 or a PDCCH repetition of AL4+AL4 from TRP-1 and TRP-2. This is essential to support because one TRP may not be able to transmit PDCCH due to PDCCH blocking (not blockage). We would like to support it using Option 2 + Alt 3 where BD candidates at a UE includes both s-TRP candidates and m-TRP candidates. |
| NTT Docomo | We share the same understanding with the above clarifications in general.  *Regarding first Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  In our understanding, without the restrictions of same AL, same DCI payload, same coded bits, option2 is the same as option3.  *Regarding second Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?*  In our understanding, there is no need to differentiate “UE selection” and “NW selection”. With option3, no matter “UE selection” or “NW selection”, UE will decode the two PDCCH candidate independently.  *Regarding to the last bullet,*  Our view is it is possible to support both option2 and option3 based on UE capability/configuration, but following aspects need to be considered.   * if both option2 and 3 are supported and combined with case1 (explicit linkage). Benefit of option3 on flexibility and dynamic switching between single and multiple TRP is limited. * If option2 is supported with case1 and option3 with case2, it will require more specification works. For option3+case2, the issues in section3.3 need to be additionally studied.   Thus, we prefer to support option2 only. |
| Samsung | Thanks for checking common understanding of other companies.  Regarding Clarification 1, we have same understanding.  Regarding Clarification 2, we have same understanding.  Clarification 3. Please find our thinking as follows.   * 1st bullet: we think that both combinations (option 3 + case 1 & option 3 + case 2) are valid combinations, but we prefer a combination (option 3 + case 2) can be implemented based on the least specification impact. * 2nd bullet: we think that option 2 combined with both case 1 and 2 can be valid combinations, but it should be required for option 2 + case 2 with large UE complexity for BD. Hence we prefer option 2 + case 1. * 3rd bullet: Based on the definition agreed in RAN1#102-e, option 2 means same AL, same DCI payload, and same coded bits. * 4th bullet: we don't understand what "UE selection" and "network selection" mean. * 5th bullet: we think that option 3 does not need extra UE capability or configuration while option 2 does. |
| QC | Response to Intel: We do not understand why option 2 should be used for “selection”. The restrictions in Option2 are unnecessary for selection. Regarding “supporting both soft-combining and UE selection”, doesn’t it mean to support both option 2 and option 3?  In Section 3.2, the proposal is “at least support option 2”. It does not preclude option 3. The intention is to at least support the option that has majority support for progress. If the intention is to say “we do not agree with option 2 unless both option 2 and option 3 are agreed together” let’s indicate that preference (we also have similar preference) instead of adding the restrictions of option 2 to “selection”, which is artificial.  Regarding network selection, my understanding of FUTUREWEI’s comment was that it did not refer to selection between sTRP and mTRP. Instead, it referred to selection between TRP1 and TRP2. For selection between sTRP and mTRP, we do not see an issue with any of the options as a different candidate (separate from the multi-TCI state candidate in option 1 or two linked PDCCH candidates in options 2/3) can be used. |
| OPPO | We share the similar understanding on the above clarifications  *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  [OPPO] Yes. RAN1#102e agreement: Each repetition has the same number of CCEs and coded bits, and corresponds to the same DCI payload  *Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?*  [OPPO] Although Mostafa explained what “network selection” refers to, we still not clear what the question is. From our understanding, UE always needs to blind decode DCI in the potential PDCCH occasions. Thus, it does not matter how NW choose to transmit a given DCI from TRP 1 or TRP2.  *It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed).*  [OPPO] No need to support two similar functionalities. It is a redundancy. Moreover, there are more spec impacts or restriction for Option 3, e.g., PUCCH resource determination, UCI multiplexing and so on. |
| vivo | We are wondering whether clarification1, 2, 3 are pretext for supporting all of those. From our point of, we should avoid duplicated functions as much as possible.  Regarding Case1 (explicit linkage), only the combination of Option2 (repetition) and Case1 is enough, there is no need to introduce the combination of Option3 (chance) and Case1, which avoids the redundant design for PDCCH enhancement.  Regarding Option2 (repetition), the time gap between the first repetition occasion and the second repetition occasion and the time gap between one of PDCCH repetitions and one of PDSCH repetitions (PDCCH repetition and PDSCH repetition may be transmitted from different TRPs) should be further studied.  Regarding Option3 (multi-chance), with Option3+implicit linkage, gNB has extra freedom, and UE can perform legacy behavior for reception, as in NCJT for eMBB in Rel16 |
| ZTE | Basically we have the same understanding with FL, DOCOMO and Samsung.  Especially for clarification 3, our views are as follow   * For selection diversity only (no soft combining), Option 3 + Case 1 (explicit linkage) or Option 3 + Case 2 (no explicit linkage) are valid combinations. * **ZTE:** agree, but option 3 + case 1 has no any benefit because of restriction * Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)? * **ZTE:** If no restriction, that is option 3. As Samsung commented, we have defined option 2 with the same AL, coded bits. * Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3? * **ZTE:** No need to discuss this. * It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed). * **ZTE:** Yes. But it is better also support independent DCI transmissions. Specifically, two DCIs may transmit PDCCH repetitions or may carry two independent scheduling information like Rel-15/16. |
| MediaTek | @ intel  In our understanding, option 2 does not mandate that the UE needs to do soft combining. Even if the DCI is repeated, the UE can just decode each separately. Thus, option 2 can actually support both soft combining and selection decoding (this can be different selection decoding in option 3 which can also support different DCI payloads).   * Clarification 2: Alt 1-1 + SFN means that the DMRS port of each PDCCH candidate is associated with both TCI states of the CORESET.   **MediaTek:** Yes   * Clarification 3: Selection diversity versus soft-combining for non-SFN schemes * For selection diversity only (no soft combining), Option 3 + Case 1 (explicit linkage) or Option 3 + Case 2 (no explicit linkage) are valid combinations.   **MediaTek:** We think only option 3 + case 1 is only valid combination. Option 3 + case 2 has many limitation.   * For soft-combining, only option 2 + Case 1 is a valid combination   **MediaTek:** Yes   * Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?   **MediaTek:** Yes, it is required. Before decoding, the UE has to know two DCI have the same payloads. Otherwise, it will increase the UE BD complexity.   * Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?   **MediaTek:** No need to discuss   * It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed).   **MediaTek:** With option 2, we can support both soft combining and selection diversity based on UE capability. We don’t need to introduce option 3. |
| Futurewei | We focus on Option 2 + Case 1 here, which is partially discussed in the email thread.  We think there may be a few schemes for Option 2 + Case 1:   * M-TRPs transmit AL4 + AL4:   + UE soft combining scheme: UE decodes using AL4 + AL4   + UE selection scheme: UE decodes with one AL4 * Network selection scheme: one TRP transmits AL4, and UE decodes with the AL4   Therefore, we think within the framework of Option 2 + Case 1, M-TRP/S-TRP dynamic switching (in a way different from what’s described below, though) and UE/network selection scheme dynamic switching can be supported.  As FL kindly replied in the email, “I think whether it is UE selection or network selection should not make a difference since in both cases UE blindly decodes both PDCCH candidates”.  We agree with that. So UE/network selection and soft combining can be supported by Option 2 + Case 1. Other options/cases are not needed.  Note that S-TRP transmission may be seen as a special case of network selection.  *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  **Futurewei**: For Option 2 UE selection, this restriction is needed. For Option 2 network selection, this restriction does not apply. |
| Fraunhofer | *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  Option 2, as per the earlier agreement, comprises the same DCI payload and the coded bits in the two PDCCH candidates. Option 2 without the restrictions would be option 3. We see option 2 as a restricted version of option 3, specifically for soft-combining purposes. Therefore, the restrictions have to be in place for option 2 as defined earlier and for it to support soft-combining.  *Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?*  No, it’s not required. In case of selection diversity, the UE independently decodes each PDCCH candidate anyway.  *It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed)*  Yes it is possible. However, the following points shall be considered: Option 2 is suitable for UEs that support either of the decoding methods (soft-combining or selection diversity). Option 3, on the other hand, may suit only to selection diversity. The specification effort to support both options can be quite high.  Simulation results from multiple companies show the effectiveness of option 2 over option 3. Considering the above points, option 2 is preferred to option 3. |
| FL Summary | It seems that companies are aligned on most of the clarification above, but not on all of them. Please see some follow-up below:  @ MediaTek: My assumption is that whether UE does soft-combining or only selection cannot be totally transparent to the spec. This is because at least how the BDs are counted toward the limit would be different. In the case of soft-combining, for two liked PDCCH candidates, 2 BDs are not enough as UE blindly decodes (including RE de-mapping / demodulation) each candidate and in addition to decoding the soft-combined one. In the case of selection only, 2 BDs are enough. If you agree with above, then through UE capability / RRC configuration, both UE and gNB should be on the same page wrt how BDs are counted. For the case that selection is configured, it is not clear why it should be limited to same AL and exactly same DCI payload (e.g. in this case one can have AL=2 and another AL=8; one can indicate K0=2 and another K0=1 if they are in different slots).  Regarding your comment “Before decoding, the UE has to know two DCI have the same payloads. Otherwise, it will increase the UE BD complexity.” Can you explain more why BD is increased if the payload and/or AL is not the same in the case that UE does not do soft-combining? To me, it seems that for selection diversity, the restrictions in Option 2 are artificial.  @vivo: The questions here were not about companies preferences, and this is not a pretext for anything. The clarifications were motivated by the questions asked during the GTW call as well as in the Emails. Please further check and let me know if more clarification is needed.  @ Futurewei: Regarding “For Option 2 UE selection, this restriction is needed”, can you please explain a bit more why restrictions are needed? If it is selection only, then why same AL / DCI payload is needed? (please also see my response to MediaTek above).  @ Fraunhofer: Regarding your comment “Option 2 without the restrictions would be option 3”. If that is the case, then why we need the restrictions in Option2 for selection only mode? I understand and agree that Option 2 can be also used for selection, but the question is that why we should not focus on Option3 for “selection only” mode given that the restrictions in Option 2 are not needed. |
| Fraunhofer2 | @FL: In our view, we choose option 2 based on its perceived advantages and performance. Simulations from multiple companies show that option 2 with soft-combining is advantageous over selection diversity. Hence, as a decoding method, soft-combining is preferred, i.e., option 2 is preferred to option 3. Given that specifying both would increase the specification effort, we prefer to focus on one of them. We are open to specifying option 2 with higher priority and having option 3 as a further option. |
| Futurewei2 | @FL: In our understanding, Option 2 UE selection is UE implementation and transparent to the gNB. So the gNB still needs to maintain the transmission scheme intended for Option 2, i.e., if both PDCCH candidates are present, they should still have the same AL/DCI payload. |
| MediaTek | @ FL  We misunderstood the question. My comment “Before decoding, the UE has to know two DCI have the same payloads.” was for option 2 with soft combining. Sorry for the confusion. However, we still don’t think we need to support option 3 by introducing “selection only” mode additionally. |
| LG | * For selection diversity only (no soft combining), Option 3 + Case 1 (explicit linkage) or Option 3 + Case 2 (no explicit linkage) are valid combinations.   : Both are valid but it is not necessary to define explicit linkage and causes redundant specification work. Also, with the linkage, scheduling flexibility of Option 3 is disappear.   * Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?   : Option 2 should have the restriction by definition.   * Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?   : Clarification may be needed for the definition of network selection. From my understanding network selection means gNB selects one between single chance PDCCH and multi-chance PDCCH. From the UE perspective, it does not cause difference in UE behaviour since UE just try to decode PDCCH candidate independently. |
| CMCC | We support both soft-combining and selection diversity scheme for Option 2. On one hand, most of simulation results show that Option 2 out performs Option 3, on the other hand, if Option 2 can support both soft-combining and selection diversity scheme, there is no need to support Option 3 with additional specification work. |
| Intel2 | @QC: thank you. I think we understand each other. yes by s-TRP/m-TRP I meant decoding from TRP-1, TRP-2 vs TRP-1+TRP-2 as clarified later by OPPO as D4, so we are on the same page that its possible also in Option 2.  @MTK, then we are on the same page that option 2 can support both soft combining and selection decoding. thanks! |
| Xiaomi | Regarding Clarification 1&2, we have same understanding.  Regarding Clarification 3. Please find our views as follows.   * For selection diversity only (no soft combining), Option 3 + Case 1 (explicit linkage) or Option 3 + Case 2 (no explicit linkage) are valid combinations.   : We think that option 3 + case 1 can be considered with lower priority, and we don’t support option 3 + case 2.   * For soft-combining, only option 2 + Case 1 is a valid combination   : We support Option 2+ Case 1.   * Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?   : Option 2 should have the restriction according to the agreement in RAN1-102e meeting   * Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?   : Case 1 is more preferred for UE selection   * It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed).   : Option 2 should be considered with higher priority than Option 3 |
| Huawei, HiSilicon | *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*  In our understanding, as OPPO mentioned, to follow the agreement in last meeting, the motivation of Option 2 is to let UE preform soft combining which means that same AL/DCI payload/coded bits should be supported. While, we are open to further support Option 3 for the UE without capability of soft combining based on the design made for Option 2 if Option 3 can be agreed. Whether to do such restriction is according to the UE capability reporting and gNB configuration.  *Question: Is there a need to differentiate “UE selection” versus “network selection” for Option 3?*  Seems that the background of the question needs to be clarified. In our view, the UE behaviour in option 3 is clear that UE needs to try the blindly detection of all the gNB configured candidates. |
| FL summary 2 | Thank you all for the discussion. Based on the views, for option 2, whether UE supports (or is configured with) soft-combining versus selection should be both supported, and this may be related to UE capability and/or how BDs are defined toward the BD limit. Based on this understanding, I updated the FL proposal 2 below. |
| Ericsson | We have the same understanding as FL on Clarifications 1 and 2.  Regarding Clarification 3, we have the following comments:   * We do not think that ‘Option 3 + Case 2 (no explicit linkage)’ is a valid combination. This is because, without explicit linkage, UE behaviour is unknown with respect to at least (i) time offset determination between detected DCI and the scheduled PDSCH/PUSCH/SRS/CSI-RS/etc., and (ii) PUCCH resource determination in case there are more than 8 PUCCH resources in a selected resource set. * We agree that for soft-combining, only ‘Option 2 + Case 1’ is a valid combination. * On the *Question: Is there any reason to consider the restrictions in option 2 (same AL, same DCI payload, same coded bits) in the absence of soft-combining (i.e. for selection diversity)?*   + Ericsson’s view is that introducing these restrictions in option 2 will simplify the linkage between the two candidates and simplify gNB/UE implementation. * Regarding the Observation: It is possible to support both soft combining (with option 2) and selection diversity (with option 3) based on UE capability / RRC configuration (if both agreed).   + Ericsson’s view is that both soft combining and selection diversity can both be supported with option 2. We do not support Option 3 as it doesn’t work without linkage in our view. With linkage, Option 3 would be similar to Option 2 which eliminates the need to specify Option 3. |
|  |  |

## **SFN Scheme**

The following was discussed during the GTW call:

**Possible Agreement**

**For PDCCH reliability enhancements,**

* **Combination A: SFN scheme + Alt 1-1 is supported**
* **Combination C1: [FDM / TDM] schemes + Alts 1-2 / 1-3 / 2 / 3 + Option 2 + Case 1** 
  + **Down-select one from Alts 1-2 / 1-3 / 2 / 3**

Given that SFN scheme is clear, we can discuss it separately as mentioned by some companies above and in the GTW session:

***FL Proposal 1*: *For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.***

* ***FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR***

|  |  |
| --- | --- |
| Company | Comments |
| Apple | Support |
| Intel | To us the key use-case for PDCCH enhancement is FR2 and we need to further check how this works in FR2 |
| NTT Docomo | We support FL’s proposal. |
| Samsung | Support FL proposal. |
| QC | We think further progress in HST-SFN AI is needed before we can agree to this. |
| OPPO | Support the proposal assuming that TDM will be supported as well |
| vivo | Regarding the ***TCI state activation,*** it is straight forward to activate two TCI states by MAC CE to support SFN scheme and the switching between S-TRP and M-TRP can be easily performed by MAC CE.  Regarding the ***impact on default beam, BFD resource for BFR,*** we think the other schemes for PDCCH enhancement (e.g. FDM or TDM) have similar issues to deal with.  Default beam, BFD resource for BFR to be discussed in multi TRP multi beam agenda. |
| ZTE | Support FL proposal.  @Intel, we think UE should be able to support two receive beams simultaneously. It is similar with PDSCH based SFN which is under discussion in AI 8.1.2.4 |
| InterDigital | Support FL proposal. |
| Futurewei | Support the FL’s proposal |
| MediaTek | Support the proposal |
| Nokia/NSB | This has a direct relation to schemes which are under discussion in HST-SFN. At least for now, we do not see this as the main scenario to agree within this sub-agenda, this is low priority. |
| LG | Support FL proposal. |
| NEC | Support the proposal. |
| Lenovo/ Motorola Mobility | Support FL proposal. For FFS part, it is suggested to add new beam identification resource for BFR as following:  ***FFS: TCI state activation for CORESET, impact on default beam, BFD resource and new beam identification resource for BFR*** |
| CMCC | Support FL’s proposal. |
| Xiaomi | Support the proposal. |
| vivo | Okay with FL’s proposal 1,  Comment to @Nokia, Per the WID for HST enhancement:   * 1. Enhancement to support HST-SFN deployment scenario:      1. Identify and specify solution(s) on QCL assumption for DMRS, e.g. multiple QCL assumptions for the same DMRS port(s), targeting DL-only transmission   SFN scheme for HST is supported in Rel-17. |
| Huawei, HiSilicon | We are open to discuss SFN, but prefer to agree on the non-SFN based solution first. |
| FL summary | Majority of companies support the proposal.  @ Nokia, Intel, QC: Please indicate if the proposal is not acceptable to you.  @ Lenovo: Since the new part has not been discussed before, let’s not add it at now. Instead, I add a note that other issues can be discussed too.  ***Updated FL Proposal 1*: *For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.***   * ***FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR*** * ***Note: The items in FFS may not be containing all FFS items, and additional issues can be discussed.*** |
| Ericsson | We support the following updated proposal from the FL with one suggestion. In our view, the last Note is not needed. It is generally understood that there could be more FFSs which can be discussed in future meetings. We prefer to only list FFSs that have a concrete description  ***Updated FL Proposal 1: For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.***   * ***FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR*** * ***~~Note: The items in FFS may not be containing all FFS items, and additional issues can be discussed.~~*** |

## **Option 2 + Case 1**

Based on majority view and the discussions, we can try the following proposal to support Option 2 with Case 1. Issues identified in Section 2.1 are listed for further study.

***FL Proposal 2*: *For PDCCH reliability enhancements with non-SFN schemes, support at least Option 2 + Case 1.***

* ***Down-select one Alt from Alts 1-2 / 1-3 / 2 / 3***
* ***FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.***
* ***FFS: BD limits, overbooking, implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, issues related to DCI format 2\_x, rate matching PDSCH around the scheduling DCI.***

|  |  |
| --- | --- |
| Company | Comments |
| Apple | OK with the proposal and suggest to add some other FFS point as follows:  **FFS: additional restriction to facilitate soft combining based detection, e.g. same starting CCE index for each repetition** |
| Intel | We are okay with this. we slightly prefer to not preclude Case 2 completely for Option 2 (mainly for the case when UE is not supporting soft-combining but supporting selection diversity reception). The reason is that linkage can potentially increase PDCCH blocking probability at the NW – although our initial results show there is little impact. |
| NTT Docomo | We support FL’s proposal. |
| Samsung | Okay with FL’s proposal. Regarding FFSs, we prefer to remove them since other aspects should not be precluded. Also, some of them (e.g., BD limits, overbooking) were already included in the previous agreement. |
| QC | We can accept this proposal for progress if the following is added:   * **Maximum number of linked PDCCH candidates is two** * **Option 3 + Case 1 is also added to the proposal**   The two above points are both related to UE complexity. For more than 2 repetitions, UE complexity (soft-combining / LLR storing) and number of BDs is even further increased. In addition, we would like to have an option without soft combining. Our preference is option 1 as UE complexity is similar to Rel. 15 / 16. However, if option 1 is not acceptable, we would like to have option 3 + Case 1. We do not understand how Option 3 + Case 2 can work given the issues discussed (but can be considered as an additional combination if the issues are addressed). |
| OPPO | Support the proposal  Question for QC regarding the UE complexity: Let’s consider a case with 2 PDCCH repetitions (for option 2) or 2 PDCCH chances (for Option 3).   * Option 2: 1 blind decoding + processing of the signals of two repetitions (e.g., channel estimation) * Option 3: 2 blind decoding2 + 2 processing of the signals of one PDCCH changes (e.g., channel estimation)   Thus, we think soft combining for option 2 will not lead to larger UE complexity compared to Option 3. Could you elaborate a bit more on the UE complexity of Option 2 + Case 1 and Option 3+ Case 1? Maybe I missed something. |
| vivo | In our view, different alternatives can be divided into two categories, **the first category is one SS with Alt1-2 and Alt2, the second category is two SS with Alt1-3 and Alt3**. Since different categories will have different rules for linkage, we prefer to define only one linkage rule in order to reduce the complexity of design for PDCCH, we can down-select one of the two categories.  In Alt3. it reuses legacy design, there may not be much spec impact, in contrast, Alt2 needs one SS associated with two CORESETs, that may increase have big spec impact, hence we prefer second category.  Regarding so many issues listed above, different approach has different issues which pretty much rely on the combination of alternatives, whether explicit or implicit linkage, repetition or multi-chance, and different DCI format configuration (e.g. common DCI or UE-specific DCI). We should avoid supporting all of the combinations, for down-selection we can start with following two alternatives:   1. **only support Option2(repetition)+Alt1-3+explicit linkage**   **FFS: which formats can be configured**   1. **only support Option3(chance)+Alt3+ implicit linkage**   **FFS: which formats can be configured. E.g. only M-DCI based on format 0-1 and 0-2 for PUSCH repetition** |
| ZTE | We are fine with the proposal in principle.  However, for the last FFS part, we have concern to support DCI format 2\_x which is usually for a group of UEs. That’s because not all UEs are suitable for multi-TRP transmission. So our suggestion is to remove the FFS part or revise it as follows  ***FL Proposal 2*: *For PDCCH reliability enhancements with non-SFN schemes, support at least Option 2 + Case 1.***   * ***Down-select one Alt from Alts 1-2 / 1-3 / 2 / 3*** * ***FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.*** * ***FFS: BD limits, overbooking, implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, rate matching PDSCH around the scheduling DCI.*** * ***FFS whether and how to support for DCI format 2\_x*** |
| InterDigital | Support FL proposal |
| Futurewei | Support the FL’s proposal  We suggest to limit the number of PDCCH candidates linked to any given PDCCH candidate. For example, this number may be [3]. |
| MediaTek | Support the proposal  @ QC  We don’t need to add option 3 + case 1 if you are concerned about the complexity of soft combining. Option 2 can support both soft combining and selection decoding based on UE capability or UE implementation. For option 3 + case 2, we have the same view as QC. |
| Fraunhofer | Support the proposal. |
| FL summary | @ Apple, QC, ZTE: I will update the proposal based on the suggestions. I would like to wait for more inputs and also for the discussions in Section 3 regarding “clarifications” (mainly related to option2 with selection only)  @OPPO: For option 2 when UE does soft-combining, # of BDs cannot be 1 as UE does two separate RE-demapping / demodulations anyway. Also, if UE decodes each PDCCH candidate separately in addition to the combined one (so that gNB can choose to send DCI on the first candidate, second candidate, or both), the # of BDs should be larger than 2. Some of these aspects were discussed in Emails in the previous meeting.  @ Vivo: We will discuss Alts separately once there is more progress. We can try to divide the Alts to 2 categories as you suggested for that discussion.  @ Vivo, SS: Unless if there is any concern, I suggest to keep the FFS so that issues can be studied by more carefully for the next meeting. These are for further study anyway.  @ MediaTek: I think once the discussions in the clarification part is sorted out, we can decide between Option2 or Option 3 for selection only mode. Please see the FL summary in Section 3. |
| Nokia | Support the FL proposal.  The FFS items that are listed seem to cover most of the issues that are needed to address. Additional issues may be also arise based on the alternatives and things we have not thought of yet. It would be safer that another bullet or note saying the following.  *Note: The items in FFS may not be containing all FFS items, and companies are encouraged to report additional changes which are expected by when supporting option 2+case 1 together with different combinations of Alts 1-2 / 1-3 / 2 / 3.* |
| LG | We support Nokia’s suggestion. In addition, there seems no objection to support TDM based Option 2 so we can add it as follows:  ***FL Proposal 2*: *For PDCCH reliability enhancements with non-SFN schemes, support at least TDM based Option 2 + Case 1.***   * ***Down-select one Alt from Alts 1-2 / 1-3 / 2 / 3*** * ***FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.*** * ***FFS: BD limits, overbooking, implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, issues related to DCI format 2\_x, rate matching PDSCH around the scheduling DCI.***   *Note: The items in FFS may not be containing all FFS items, and companies are encouraged to report additional changes which are expected by when supporting option 2+case 1 together with different combinations of Alts 1-2 / 1-3 / 2 / 3.* |
| NEC | Support the proposal.  And we think number of linked PDCCH candidates should be 2. |
| Lenovo/ Motorola Mobility | Support the FL proposal. |
| CMCC | Support FL’s proposal.  Regarding to the first sub-bullet “Down-select one Alt from Alts 1-2 / 1-3 / 2 / 3”, we think that different Alts may have different pros and cons, it may be possible to suppot one or more alternatives, so we prefer to revise the proposal as “Down-select one or more Alts from Alts 1-2 / 1-3 / 2 / 3”. |
| OPPO2 | Ok with either FL’s proposal or LG’s version  Response to FL: From our understanding, there seem four different implementations for Option 2 form UE perspective.  D1: selection diversity only. UE will decode each PDCCH repetition separately   * Complexity: x1 = 2 BDs   D2: Soft-combining only. UE will only jointly decode the two PDCCH repetitions   * Complexity: 2 BDs > x2 > 1 BDs (due to two separate RE-demapping / demodulations)   D3: Selection diversity + soft-combining, UE will decode the 1st PDCCH and jointly decode the two PDCCH repetitions   * Complexity: x3 > 2 BDs   D4: Selection diversity + soft-combining, UE will decode the 1st PDCCH and the 2nd PDCCH separately, and jointly decode the two PDCCH repetitions   * Complexity: x4 > 2 BDs (or > 3 BDs ? ), x4 > x3  |  |  | | --- | --- | |  | UE complexity compared to Option 3 + Case 1 | | D1 | Similar or same | | D2 | Less | | D3 | Higher | | D4 | Higher |   If I understood correctly, when you were talking about “soft combining”, you referred to D4, which requires the highest UE complexity. However, UE has other choice(s), e.g., D2. Thus, we don’t think the UE complexity issue can justify the support of Option 3 + Case 1. Different implementations can be reported by UE capability and/or configured by gNB (depends on the output of further discussion). |
| Intel2 | @OPPO2, @MTK – similar view, and we believe D1-D4 can be further discussed for Option 2  @LG – we don’t see why restriction of TDM is needed  @QC – we are okay to add “Maximum number of linked PDCCH candidates is two” |
| Xiaomi | Support the proposal.  And we suggest to limit the number of linked PDCCH candidates to 2. |
| vivo | Okay with FL’s proposal, and we agree with Samsung’s comment. These issues listed by FL are concerned not only under Option2, but also Option3, and some other issues (e.g. rules about default beam depends on 1or2 TCI states activated for lowest CORESET ID, enhancement for BFD procedure depends on soft bits combining or not) are not included in this proposal, there are certainly other issues which may turn up later.  We should focus on down-selection for combination of different Options and different Case and different Alt at this meeting, the FFS can be removed from proposal for now and companies can further consider potential impacts next meeting |
| Huawei, HiSilicon | Support the main bullet. We are open to further discuss on the Alts to be combined with option 2.  @LG, we think FDM can also be supported by option 2 easily, so we don’t see the necessity to limit it to TDM. |
| FL Summary | @ OPPO: Yes, I was referring to D4 above. I agree that the details for BD should be discussed further.  @ LG: The discussions related to TDM versus FDM can happen later, and it depends on the Alt we choose. For example, with Alt3, there is no difference between TDM and FDM from specification point of view (depends on CORESET / SS configurations).  @ Vivo: Yes, I agree that some of the issues may be also needed for other options. At least for option 2, there seems to be a common understanding that these issues should be discussed (it does not mean change is required for each of them). From FL point of view, I see the benefit of listing the identified items for further study. Since these are FFS anyway, there should not be a major concern (also a note is added that other issues can also be discussed).  @ Apple, QC, ZTE, CMCC, Intel, Nokia: Your suggestions are captured in the updated proposal below:  ***FL Proposal 2*: *For PDCCH reliability enhancements with non-SFN schemes, support at least Option 2 + Case 1.***   * ***Maximum number of linked PDCCH candidates is two*** * ***Option 2 + Case 1 supports both soft-combining and selection decoding***   + ***FFS: Details including how the two PDCCH candidates are counted toward the BD limits and impact on overbooking, if any, for both cases of soft-combining and selection decoding*** * ***Down-select at least one Alt from Alts 1-2 / 1-3 / 2 / 3*** * ***FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.***   + ***FFS: additional restriction to facilitate soft combining*** * ***FFS: ~~BD limits, overbooking,~~ implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, ~~issues related to DCI format 2\_x,~~ rate matching PDSCH around the scheduling DCI.*** * ***FFS: whether and how to support for DCI format 2\_x*** * ***Note: The items in FFS may not be containing all FFS items, and companies are encouraged to report additional changes which are expected by when supporting option 2+case 1 together with different combinations of Alts 1-2 / 1-3 / 2 / 3.*** |
| Ericsson | We supported the following updated proposal from the feature lead with a few suggestions.  Firstly, we prefer to remove the last Note. In our view, the Note doesn’t seem meaningful. It is understood that there may be additional FFSs that may be brought up in future meetings. So, we suggest removing this Note.  Furthermore, for the alternatives, we prefer to down select one of the Alts to minimize spec impact. Hence, we suggest to remove ‘at least’  In addition, we support limiting the maximum number of linked PDCCH candidates to two.  Our suggested changes are highlighted in yellow.  ***Updated FL Proposal 2: For PDCCH reliability enhancements with non-SFN schemes, support at least Option 2 + Case 1.***   * ***Maximum number of linked PDCCH candidates is two*** * ***~~Option 2 + Case 1 can supports both soft-combining and selection decoding~~*** * ***FFS: Details including how the two PDCCH candidates are counted toward the BD limits and impact on overbooking, if any~~, for both cases of soft-combining and selection decoding~~*** * ***Down-select ~~at least~~ one Alt from Alts 1-2 / 1-3 / 2 / 3*** * ***FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.***   + ***FFS: additional restriction to facilitate soft combining*** * ***FFS: ~~BD limits, overbooking,~~ implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset  for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, ~~issues related to DCI format 2\_x,~~ rate matching PDSCH around the scheduling DCI.*** * ***FFS: whether and how to support for DCI format 2\_x*** * ***~~FFS: SFN + Option 2~~*** * ***~~Note: The items in FFS may not be containing all FFS items, and companies are encouraged to report additional changes which are expected by when supporting option 2+case 1 together with different combinations of Alts 1-2 / 1-3 / 2 / 3.~~*** |

## **Option 3**

For Option 3, both Case 1 and Case 2 are possible. Discussions are required for further down-selection. Multiple companies pointed out issues with respect to Option 3 + Case 2 for which there may not be an easy solution. Some of the issues are listed here based on the summary in Section 2.1 for more technical discussions. Companies are welcome to clarify if they see an issue, and if yes, how it can be fixed given that there is no explicit linkage between the two PDCCH candidates:

* Implicit PUCCH resource determination for >8 PUCCH resources in the resource set
* Scheduling offset for “timeDurationForQCL”
* Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH
* Rate matching PDSCH around the scheduling DCI(s)
* Group-common DCIs such as TPC command

Please discuss the technical details of the issues above as well as any other potential issues to align the understanding on pros / cons of Case 1 versus Case 2 for Option 3.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | Do not support option 3 |
| NTT Docomo | In our view, Option2 is sufficient. There is no need to support Option3 additionally.  Meanwhile, for Option3, without explicit linkage pre-defined or configured, enhancement on DCI will be needed to solve the above issues. |
| Samsung | We do not understand why the issues are only related to case 2. These are also applied to case 1. Also, they can be resolved by proper configuration/implementation. For example, the NW can schedule a UE with the same behavior applying on PDSCH default beam for repeated PDCCHs. In that sense, we don’t think explicit linkage (case 1) is really needed for Option 3. |
| QC | In our understanding, the issues above are not easily solvable for Option 3 + Case 2. For Case 1, the ambiguities can be resolved due to the linkage. It would be good if interested companies can clarify the details. |
| OPPO | Not support Option 3 |
| vivo | As we mentioned above,   * For Case1 (explicit linkage), only Alt1-3 is enough. Combination of Case1+Alt3 is basically same function hence two similar designs is not necessary. * For the most of questions (e.g. scheduling offset, Out-of-order, rate matching) listed above, we can reuse NCJT mechanism in Rel16, where different CORESET is associated with one CORESET pool index. * Alt3 is only supported with M-DCI PUSCH repetition to reduce effort of spec and complexity of design, Alt3 is not applicable to Group-common DCIs. |
| ZTE | Option 3 + Case 2 provides most flexibility since two DCIs can transmit PDCCH repetitions or can carry independent scheduling information like as Rel-15/16. gNB can dynamically switches to Rel-15/16 scheduling or switches to repetition modes so as to enhance the PDCCH reliability especially in blockage scenarios.  Here is our view for the above issues   * Implicit PUCCH resource determination for >8 PUCCH resources in the resource set   **ZTE**: several solutions can be considered. One solution is up to UE to select one PUCCH resource based on one of two PDCCH if UE correctly receives both DCIs. gNB will detect PUCCH twice, but only one PUCCH can be successfully detected. The second solution is, UE can transmit PUCCH twice, but it may cause additional UE power. Another solution is to restrict two PDCCHs must lead to the same PUCCH resource selection, this is easy to be implemented by TDMed PDCCH repetition.   * Scheduling offset for “timeDurationForQCL”   **ZTE:** Solution 1, gNB can ensure the slot offset between both PDCCH and the scheduled PDSCH is either smaller or larger than the threshold. Solution 2: If UE receives both DCI, one of two default TCIs can be predefined, e.g. use the indicated TCI.   * Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH   **ZTE:** The solution can be similar with option 2 + case 1. One solution is to define a time reference for one of two PDCCHs. Taking QC’s picture as an example, a time offset (maybe a negative value) for the second candidate can be introduced, UE can assume second PDCCH is transmitted in the time position as the same as the first PDCCH candidate. The other solution is to let gNB avoid the following scheduling.  In our view, option 2 will have the same issue. One of PDCCH candidates will be assumed as the time reference of the other PDCCH. So for option 3 + case2, the time reference can also be defined for each PDCCH.     * Rate matching PDSCH around the scheduling DCI(s)   **ZTE:** This is not a big issue. Dynamic rate matching patterns have been introduced since Rel-15, the corresponding CORESET resources can be configured in that. Another solution is up to implementation, e.g. gNB ensure scheduling DCIs not overlap with PDSCH resource.   * Group-common DCIs such as TPC command   **ZTE:** As we commented before, we don’t think multi-TRP can be supported for common group DCIs. |
| Futurewei | Do not support Option 3 |
| MediaTek | Do not support Option 3 |
| FL summary | @ Samsung: The reason that these issues are listed for Case 2 only is that it is not clear to some companies how the ambiguous cases can be addressed given that there is no explicit linkage.  @Vivo: Can you clarify how “we can reuse NCJT mechanism in Rel16, where different CORESET is associated with one CORESET pool index” can help for the issues above? Also, are you suggesting that Option3 + Case 2 can be used only when UE is configured with two CORESETPoolIndex values? I do not think this is a common understanding among companies.  @ ZTE: Thanks for providing some details. I think it helps a lot. Some follow-up questions below:  For “a time offset (maybe a negative value) for the second candidate can be introduced, UE can assume second PDCCH is transmitted in the time position as the same as the first PDCCH candidate”, are you thinking that first/second is based on some sort of linkage?  For rate matching issue, if “Dynamic rate matching patterns” is used, it is no longer rate matching around the scheduling DCI. Instead, rate matching would be around the resources of the whole CORESET. What you suggested can address the issue to some extend but then the unit of rate matching is much less granular.  For the other solutions / other issues: It seems to me that the spec changes and/or limitations needed here (for Case 2) are different than those needed for Case 1 (with either option2 or option 3) based on your explanations. Then, we may not have a common design / framework between Option 2 and Option 3 (if case 2 is selected for option3). If that’s the case, the support of Option 3 + Case 2 can be discussed as an additional scheme.  For group-common DCI, I think it is ok to make it FFS to study the issues (as you suggested for FL proposal 2). However, we cannot assume here we should not worry about the implications for group common DCIs. The structure of DCI formats 2\_x is designed in such a way it can be also used for transmission to a single UE. Also, if there are multiple UEs that see the same two TRPs (e.g. co-located TRP, or UEs at the cell-edge of two TRPs) group common DCI can be sent to those UEs. |
| Nokia | Do not support. Having option 2 is more than sufficient to provide reliability requirements. No need to support redundant solutions. |
| LG | * Implicit PUCCH resource determination for >8 PUCCH resources in the resource set   : We have similar view with ZTE. Scheduler avoids the issue by configuring the same PUCCH resource or UE can use any one of the PUCCH resources when it successfully decodes multiple DCIs scheduling the same PDSCH.   * Scheduling offset for “timeDurationForQCL”   : When DCI 1 to PDSCH offset satisfies the threshold but DCI 2 does not, scheduler can indicate the same TCI state of DCI 1 as default beam of PDSCH.   * Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH   : Similar view with ZTE, time offset may be introduced. It does not mean explicit linkage and it just reference time to determine whether OOO. |
| NEC | Do not support option 3, we think option 2 is enough. |
| Lenovo/ Motorola Mobility | We support option 3. Without explicit linkage of PDCCH resources, gNB has the flexibility to use the PDCCH resources jointly or separately. This gives gNB the freedom to decide how much reliability to give to each DCI transmission. This also allows gNB to reduce the blocking probability. |
| CMCC | Not support Option 3 |
| Xiaomi | Option 3 + Case 1 can be considered with lower priority. Do not support Option 3+ Case 2. |
| vivo | Following was agreed in last RAN1 meeting:   * Option 3 (multi-chance): Separate DCIs that schedule the same PDSCH /PUSCH /RS/TB/etc. or result in the same outcome.   + Study both cases of DCIs in the same slot and DCIs in different slots   The behavior of UE reception is not only difference between Option2 and Option3, Option3 provides more flexibility compared to option2.   * No need to use same AL. Each TRP can dynamically select suitable AL for corresponding DCI, which can avoid wastage of PDCCH resource. * For M-DCIs scheduling multiple PDSCH/PUSCH repetition occasion, the slot offset indication (e.g. K0) can be different, the fields for MCS or resource allocation can be different, so the payload in every DCI must be different.   Regarding FL’s comment to vivo  Please find below our consideration:  The Rel-16 spec supports Out-of-order scheduling if configured two different CORESET pool index, and rate matching can reuse the present rule, so with minor changes, e.g., predefining two HARQ process IDs indicated in different multi-DCIs are same for combination of Optin3+Alt3, the issues can be easily solved. Below is excerpt from 38.214 .  ====================for PDSCH scheduling================  “When PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *CORESETPoolIndex,* the following operations are allowed:  - For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start receiving a first PDSCH starting in symbol *j* by a PDCCH associated with a value of *CORESETpoolIndex* ending in symbol *i*, the UE can be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH associated with a different value of *CORESETpoolIndex* that ends later than symbol *i*.  - In a given scheduled cell, the UE can receive a first PDSCH in slot *i*, with the corresponding HARQ-ACK assigned to be transmitted in slot *j*, and a second PDSCH associated with a value of *CORESETpoolindex* different from that of the first PDSCH starting later than the first PDSCH with its corresponding HARQ-ACK assigned to be transmitted in a slot before slot *j*.”  ====================for PUSCH scheduling================  “If a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *CORESETPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *CORESETPoolIndex,* for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH associated with a value of *CORESETpoolIndex* ending in symbol *i*, the UE can be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH associated with a different value of *CORESETpoolIndex* that ends later than symbol *i*. ” |
| ZTE2 | @FL, please see my reply as follows  For “a time offset (maybe a negative value) for the second candidate can be introduced, UE can assume second PDCCH is transmitted in the time position as the same as the first PDCCH candidate”, are you thinking that first/second is based on some sort of linkage?  **ZTE**: This can be assumed a kind of implicit linkage, but it is different from the linkage defined for option 2. Actually, it is just a time reference for a DCI detection, UE does not need to be aware of the other DCI.  For rate matching issue, if “Dynamic rate matching patterns” is used, it is no longer rate matching around the scheduling DCI. Instead, rate matching would be around the resources of the whole CORESET. What you suggested can address the issue to some extend but then the unit of rate matching is much less granular.  **ZTE**: What I suggested was nothing to do for the current spec, it is up to implementation. gNB can also ensure non-overlapping between PDCCHs and PDSCH. In addition, I think option 3 + case 1 may also have the same issue if gNB can freely choose single-TRP or multi-TRP PDCCHs. For example, if gNB only transmit DCI1 but not transmit DCI2, does UE rate match around DCI1 since DCI1 and DCI2 are explicitly linked.  For the other solutions / other issues: It seems to me that the spec changes and/or limitations needed here (for Case 2) are different than those needed for Case 1 (with either option2 or option 3) based on your explanations. Then, we may not have a common design / framework between Option 2 and Option 3 (if case 2 is selected for option3). If that’s the case, the support of Option 3 + Case 2 can be discussed as an additional scheme.  **ZTE**: We are open for option 3+case1 if it can provide sufficient flexibility, e.g. dynamic switching between PDCCH repetition and independent scheduling. After agree option 2 + case 1, we can further discuss it. |
| Huawei, HiSilicon | Option 3 + case 1 can be covered by option 2. With option 2, if there’s no soft combining at UE side it will essentially be option 3, and they are of the same specification framework. The soft combining can be according to both the UE capability reporting and gNB configuration/scheduling.  For option 3 + case 2, it seems very challenging considering the listed issues. |
| FL summary 2 | Thanks for the discussions, especially ZTE and vivo for providing more details, which I think help to clarify the specification impacts. It is clear that Option3 is not supported by a large number of companies (11 companies). Let’s focus on option 2, and other options can be further discussed later when there are more supports. |
| Ericsson | We agree with the FL’s latest assessment. Ericsson does not support Option 3 also at this stage. We can discuss other options later. |

## **Option 1**

The following limitations have been mentioned for option 1:

* For FDM, AL=1 is not supported when REG bundle=6
* For TDM, 1-symbol CORESET is not supported. For 3-symbol CORESET, equal allocation is not possible.
* AL16 + AL16 is not supported.

Please discuss any other limitation, or comment on the limitations above for option 1.

|  |  |
| --- | --- |
| Company | Comments |
| Intel | * Support of selection diversity reception (that can be used for Option 2 or option 3) * Not clear how to support dynamic switching between s-TRP and m-TRP PDCCH (“network selection”) * Not clear how to generalize to inter-slot repetition if necessary |
| Samsung | Not support Option 1. Based on simulation results, we observed that Option 1 does not have any performance benefit compared to Option 2 especially in blockage scenario. |
| QC | * For FDM with AL=1 with REG bundle=6: Network can configure other REG bundle size. Also, AL=1 is not the main scenario of interest. Even with Option 2 / 3, we do not have an equivalent to AL=1 in terms of # of CCEs. So, if anything, option 1 is more flexible (since 1 CCE DCI is possible with option 1, e.g., when REG bundle size is not 6, but it is not even possible with options 2 and 3) * For TDM with 1-symbol CORESET: Network can configure 2-symbol CORESET. Even with options 2 / 3, at least 2 symbols are needed overall for TDM by definition. Hence, we cannot view that as limitation of Option 1. * Regarding AL16+AL16: First, it is not fair to compare option 1 with AL=16 and options 2 and 3 with AL16+AL16. Second, AL16+AL16 is not related to reliability. It is related to the operation point, i.e., SINR regime. If there is an interest to extend the PDCCH coverage (i.e. min SINR operating point), the fair comparison is to compare AL16+AL16 (in options 2 / 3) with AL32 (in option 1). * Dynamic switching between sTRP and mTRP can be supported by using a different CORESET, or by configuring REG bundles with TCI state 1 / TCI state 2 in the same CORESET so that   + some PDCCH candidates are transmitted only from TRP1   + some PDCCH candidates are transmitted only from TRP2   + some PDCCH candidates are transmitted from both TRPs * Not clear why inter-slot is required given the low latency requirements especially when it comes to scheduling info (i.e. PDCCH) |
| OPPO | Not support Option 1 due to the above-mentioned limitations/restrictions. |
| vivo | First, PDCCH enhancement should avoid duplicated functions, in our view, compared to SFN scheme, there is no benefit of Option1 both from performance and complexity point of view. Hence, the discussion should be not only for limitations, the benefit against SFN should also be discussed.  Our understanding of pros of SFN against Option1 as follows:   1. SFN is suitable for HST whereas option1 TDM and FDM cannot support efficiently 2. Performance of SFN (with small delay CDD between 2 TRPs) is similar to FDM joint encoding and FDM separate encoding (Ref R1-2005364 in #102e) 3. SFN and FDM have same latency 4. SFN can be supported by 1 COREST with two active TCI states, whereas complicated design FDM/TDM with regard to TCI state association and REG bundle/symbol 5. TDM in symbol granularity doesn’t support 1 symbol CORESET and is not straight forward with 3 symbols CORESET. There are no evaluations results showing benefits. |
| ZTE | Not support option 1 as SFN has the similar performance, functionality and complexity, |
| Futurewei | Non-SFN Option 1 seems not needed. |
| MediaTek | Do not support Option 1. |
| Nokia | We would be ok to consider. However, it looks like ‘No’ for option 1. |
| LG | Not support.  Most companies show option 2 achieves equal or better performance that option 1. So performance wise, it is not reasonable to introduce option 1 in addition to option 2. If some company have concern on UE implementation burden for option 2, we can consider SFN based enhancement providing 3dB power boosting in non-blockage scenario and diversity gain in blockage scenario. |
| Lenovo/ Motorola Mobility | We are fine to consider it as a complementary enhanced scheme. |
| CMCC | Not support Option 1 |
| Intel2 | @QC: Inter-slot is beneficial to significantly improve PDCCH blocking probability by jointly scheduling PDCCH over 2 slots at a time as shown in our tdoc – yes it comes at a cost of latency (but in FR2 it may be acceptable latency). The reason for improvement is because a UE can be allocated a candidate in slot-1 and another candidate in slot-2 for soft-combining that can improve CCE utilization at the gNB. |
| Xiaomi | Not support Option 1 since it doesn’t have better performance than SFN |
| Huawei, HiSilicon | Besides the listed limitation, there are also following problems for option 1. Therefore, we don’t support option 1.   * The performance of Option 1 depends heavily on the TCI mapping patterns, considering different CORESET configurations, e.g., interleaving or not, REG bundle size, #of REGs, interleaving size, AL and etc. So the pattern design will be very complicated. * Wideband channel estimation may be limited for Option 1 |
| FL summary 2 | It is clear that Option1 is not supported by a large number of companies (11 companies). Let’s focus on option 2, and the other options can be further discussed later when there are more supports. |
| Ericsson | Ericsson also does not support Option 1. As we discussed in our contribution, one of the main issues with Option 1 is that its performance in presence of channel blocking is highly dependent on the partition of coded PDCCH bits between TRPs, which depends on not only REG/REG bundle/CCE to TRP/TCI state mapping, but also on DCI payload size and aggregation levels. Therefore, one mapping pattern which is good for one AL/payload size may not be good for a different AL/payload size. This makes it very difficult to standardize Option 1. |

# **Round 3 Discussions**

The following were agreed:

***Agreement***

*For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.*

* *FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR*

***Agreement***

*For PDCCH reliability enhancements with non-SFN schemes, support at least Option 2 + Case 1.*

* *Maximum number of linked PDCCH candidates is two*
* *FFS: Details including how the two PDCCH candidates are counted toward the BD limits and impact on overbooking, if any*
* *Down-select at least one Alt from Alts 1-2 / 1-3 / 2 / 3*
* *FFS: Linking options such as a fixed rule based on the same PDCCH candidate index, based on start CCE, based on configuration, etc.*
  + *FFS: additional restriction to facilitate soft combining*
* *FFS: implicit PUCCH resource determination for >8 PUCCH resources in the resource set, scheduling offset for “timeDurationForQCL”, Out-of-order / in-order definition for PDCCH-to-PDSCH and PDCCH-to-PUSCH, DAI for Type-2 codebook, Slot offset  for scheduling the same PDSCH/PUSCH/CSI-RS/SRS, rate matching PDSCH around the scheduling DCI.*
* *FFS: whether and how to support for DCI format 2\_x*

## **Alternatives**

For round 3, we can focus on down-selection for alternatives for combination Option 2 + Case 1 for non-SFN schemes (i.e. to address “• Down-select at least one Alt from Alts 1-2 / 1-3 / 2 / 3)

* Alt 1-2 (one CORESET with 2 TCI states; two PDCCH candidates in the same SS set)
* Alt 1-3 (one CORESET with 2 TCI states; two PDCCH candidates in different SS sets)
* Alt 2 (one SS set associated with 2 different CORESETs)
* Alt 3 (two SS sets associated with corresponding CORESETs)

Below is a summary considering on the discussions in Round 1 regarding alternatives (Section 2.4):

* In Alt 1-2 or 2 (one SS set), different monitoring occasions of the same SS set should be associated with different TCI states (in Alt 1-2) or different CORESETs (in Alt 2) in order to support TDM, which requires additional “association” in monitoring occasion dimension.
* In Alt 1-3 or 3 (two SS sets), TDM can be supported naturally. Time-domain behaviour of the two SS sets may require some alignment.
* In Alt 1-3, it is required to associate a SS set to a TCI state out of the two TCI states of the CORESET (TCI state becomes a property of the SS set)
* In Alt 1-2, it is required to link different PDCCH candidate incides of the SS set for FDM
* It is not clear how Alt 1-3 can support FDM.
* Alt 3 can support both TDM and FDM with same framework. TCI framework of CORESET in R15 can be reused, and the association between SS set and CORESET in R15 can also be reused.
* Alt 2 or 3 require two CORESETs, while Alt 1-2 / 1-3 can work with one CORESET.
* In Alt 1-2 / 1-3, some changes are required due to two TCI states for a CORESET (which may be similar to changes required for Alt1-1 that is agreed for SFN)
* Most (not all) of the FFS items in the second agreement (for non-SFN scheme) are applicable to all Alts.

It is important to agree on at least one Alt so that we can focus on specification impacts in the next meeting. Considering the majority view and the considerations summarized above, the following is proposed:

***FL Proposal 3*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, support Alt3 (two SS sets associated with corresponding CORESETs).***

|  |  |
| --- | --- |
| Company | Comments |
| LG | Not support. We have agreed one CORESET with 2 TCI for SFN PDCCH. Option 2 can be supported with the similar framework, i.e., with Alt 1-2 or 1-3. If Alt 3 is introduced it may cause CORSET shortage since it consumes two CORESETs. Also, even though the two CORESET have almost same information except for TCI state, it needs independent RRC configuration in Alt 3, increasing signaling overhead. |
| Apple | We support Alt1-3. Alt2/Alt3 may need to introduce more CORESETs. In addition, we are not sure whether we should consider the case that two PDCCH repetitions are in different slot, maybe it is good to restrict them within a slot. |
| CMCC | We support both Alt1-3 and Alt3. Since only three CORESETs are supported for UE, to consider the CORESET configuration flexibility, Alt 1-3 occupies less CORESET than Alt 3. However, Alt 1-3 needs additional spec enhancement to support two TCI states for one CORESET. Considering the pros and cons for different alternatives, both Alt 1-3 and Alt 3 could be supported for Option 2, and left to gNB for selection. |
| Spreadtrum | Support FL’s proposal.  Rel-16 has introduced two set of CORESETs to enable CORESET configuration per TRP, and total #COERSET has been increased up to 5 depending on UE capability. Given that, we think Alt3 is one natural way to support option 2 + case1, and compatible with PDSCH transmission across M-TRP. |
| ZTE | Support FL proposal. Since above alternatives have the same functionality, we don’t think more than one can be supported.  Alt1-2 and 1-3 are less flexible than Alt3 which can support both FDM and TDM multiplexing between two PDCCH repetitions. |
| Xiaomi | Not support the FL proposal. Alt 3 will consume two CORESETs.  And we support Alt 1-3 since we have agreed one CORESET with 2 TCI for SFN PDCCH |
| OPPO | We support Alt1-2.   * We should design the detailed features based on the same framework for both SFN and Non-SFN schemes. Thus, Alt.2 and Alt.3 should be precluded as it introduces a different framework compared to SFN scheme. * For Alt.1-3, it violates the basic design principle of CORESET-level beam indication, which was an outcome of lengthy and intensive discussion in Rel-15. |
| Samsung | Support FL proposal. |
| Huawei, HiSilicon | Support FL’s proposal. Alt 3 provides high flexibility to allow separate configuration of SS set and CORESET per TRP. Also, the linkage between candidates can have a unified design for both TDM and FDM based scheme. We are open to discuss how to define the linkage between candidates. We can also consider to reuse R16 scheme to extend maximum number of CORESET to 5 per BWP.  For Alt 1-2 quite different spec impact is needed for TDM and FDM based scheme. For TDMed scheme, different monitoring occasions should be associated with different TCI, and the candidates associated with different TCI isare linked, the TCI mapping as well as the linked rule should be specified. While for FDMed scheme, linkage of candidates should be defined within one monitoring occasion of a SS set and the association of candidates and TCIs should also be specified.  With Alt 2, the candidates from two CORESETs compose one SS set, therefore the framework of the SS set have to be modified, while it can be reused for alt 3.  Our 2nd preference is Alt 1-3. Compared with Alt 3, one more spec impact is that TCI should be defined per SS set. |
| NTT Docomo | Support FL proposal.  We are fine with either alt.1-3 or alt.3. Alt.1-3 cost less CORESETs than Alt.3, while Alt.3 is more flexible since different CORESETs can be configured.  With Alt. 1-2/2, to support TDM, association between monitoring occasions and TCI states/CORESETs is needed. Furthermore, both intra-slot and inter-slot repetition need to be considered. We do not support alt.1-2/2. |
| Fujitsu | Support FL’s proposal. |
| Futurewei | Support the FL’s proposal.  From the above summary, Alt3 is the most versatile/straightforward approach and least restrictive. |
| Lenovo/ Motorola Mobility | Support FL’s proposal on account of flexible configuration for Alt3. |
| QC | Support the FL proposal.  Regarding # of CORESETs in Alt3, we think the 2 CORESETs needed can also be used for single-TRP / legacy behavior (e.g. by using other SS sets). Hence, we do not think “consuming two CORESETs” is an issue.  In addition, the changes required for SFN PDCCH are anyway not the same since SFN is agreed with Alt 1-1 (and not Alt 1-2 or 1-3). |
| MediaTek | Support FL’s proposal |
| Convida Wireless | Support FL’s proposal |
| Intel | Support FL proposal. Some reasoning below:   * CORESET shortage is not an issue because the linked CORESETs can also be used for other SS-sets (s-TRP transmission for e.g.) as QC mentioned * 2 CORESET does not mean more UE complexity than 1 CORESET as CCE/BD limits will be used to determine complexity (separate discussion) * Alt-1-2/1-3 implies strict TDM multiplexing of repetitions which is quite limiting as ZTE mentioned * Alt-3 we can use existing CORESET/SS-set definitions and association with TCI states |
| Fraunhofer | Support FL’s proposal for the following reasons:   * Extra specification effort is required to map the TCI-states to the PDCCH candidates or the SS sets in the case of Alt1-2 and Alt1-3. * Alt-3 is flexible and supports both TDM and FDM. Moreover, for multi-TRP purposes, the number of CORESETs supported per BWP has been increased to 5. Hence, supporting Alt-3 won’t be a problem. |
| InterDigital | Support FL’s proposal. |
| Ericsson | Support FL’s proposal. We think Alt.2 may provide a simpler linkage between 2 PDCCH candidates but we are ok with Alt.3.  For Alt.1-2/1-3, at least for supporting TDM operation between TRPs, the current CCE to REG mapping is no longer feasible and a new mapping is required, which may require large specification work. |
| vivo | Not support.  We prefer Alt1-2 an Alt1-3 for combination Option2+Case1, if further down-selection is needed for Opiton2, we support at least Alt 1-3.  Since SFN scheme has been supported by introducing one CORESET with two TCI states, which can be seen as the main feature for PDCCH enhancement in Rel17 which differentiates the legacy design, from spec impact point of view it is better to keep similar approach for SFN and Option2. Furthermore, Alt1-3 and Alt1-2 both can support Option2 with TDM (e.g. configure special monitoring occasions associated with respective TCI states) and FDM scheme (e.g. configure odd/even candidate index associated with respective TCI states), with Alt1-3 since the number of SS can be seen as the identification to differentiate SFN and Option2, for instance.  Regarding Alt2 and Alt3, at least 2 CORESETs are needed. In Rel16, up to 3 CORESETs can be configured on each BWP on a serving cell. For Alt2 or Alt3, number of CORESETs are limited, besides two CORESETs for PDCCH repetition are configured, once CORESET0 is configured again, there is no CORESET allowed to the search space set provided by *recoverySearchSpaceId* for monitoring PDCCH in BFD procedure. |
| Nokia/NSB | Do not support. We think that Alt.3 is a restricted scenario as two CORESETs has to be used always, and we may not able to increase the number of CORESETs that the UE support. The better way to handle this would be Alt 1-2.  We understand that there would be much more spec impact, but as this may be the only scheme that might need further discussion, we think there is enough time to support this. |

**4.1.1. FL Update**

The company views are summarized as:

* Support Alt 3 (18 companies): CMCC, Spreadtrum, ZTE, Samsung, Huawei, HiSilicon, NTT Docomo, Fujitsu, Futurewei, Lenovo/ Motorola Mobility, Qualcomm, MediaTek, Convida Wireless, Intel, Fraunhofer, InterDigital, Ericsson
* Support Alt 1-3 (5 companies): LG, Apple, CMCC (in addition to Alt 3), Xiaomi, vivo
* Support Alt 1-2 (3 company): OPPO, vivo, Nokia/NSB

The pros and cons of all alternatives are well-understood as this topic is being discussed for the third time. The main reason from companies who do not support Alt3 is that it requires two CORESETs. However, it should be noted that the two CORESETs can also be used for other SS sets as multiple companies mentioned. At the same time, the limitation in the scenario mentioned by vivo (when both CORESET 0 and CORESET associated with *recoverySearchSpaceId* are in the active BWP) can be discussed further. If # of CORESETs are 3 (i.e. in the absence of multi-DCI based mTRP), then CORESET0, if present, can be used as one of the two CORESETs in Alt3.

From FL point of view, a decision is needed so that details can be discussed in the next meeting (e.g. the linking options heavily depend on the Alt). At the same time, there are companies who prefer to not close the door to more than one Alt. For progress and given the majority view, the following proposal can be considered.

***Updated FL Proposal 3*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, at least support Alt3 (two SS sets associated with corresponding CORESETs).***

Given the above summary, please comment only if the updated proposal is not acceptable to you or if you have a comment not mentioned before.

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | We prefer to remove “at least”. |
| Nokia/NSB | Ok to compromise. |
| Apple | Alt3 cannot work for PCell, where one CORESET is used as CORESET0, another CORESET is used for CORESET-BFR. There is only 1 CORESET left. However, to increase number of CORESETs would increase UE complexity. Alt1-2 or Alt1-3 may be a better solution. |
| Huawei, HiSilicon | Support the FL proposal. |
| OPPO | Although we prefer Alt.1-2, by considering the majority views, we can compromise to accept the updated FL proposal assuming that “at least” is remove. We don’t want to support duplicated mechanisms for the same purpose. One mechanism is sufficient. |
| LG | Not support. We also think there is CORESET shortage issue for PCell, as Apple mentioned. In addition, CORESET 0 is used for broadcast so Tx beam is not optimized for UE specific PDCCH. As a result, there may be performance loss if CORESET 0 and another CORESET are used for UE specific PDCCH repetition.  Regarding then number of CORESET, some proponents of Alt 3 mentioned up to 5 CORESETs can be configured for R-16 MTRP, so # of CORESET is sufficient. However, if UE does not have capability of multiple CORESET pools or gNB does not configure multiple CORESET pools, maximum # of CORESET is still 3.  Regarding FDM, some companies argue one of benefits of Alt 3 is to support both FDM and TDM but Alt 1-3/1-2 can support both as well with linkage of PDCCH candidate and TCI state. |
| ZTE | Support the FL proposal.  In our view, there is no limitation to use option 2+ cae 1 for CORESET for BFD. Also, CORESET0 and another CORESET can also be used for option 2 + case 1. |
| CATT | We don’t support this proposal.  Considering the amount of CORESETs occupied in Alt.2 and 3, Alt.1-2 or 1-3 is preferred.. |
| vivo | Although there are many companies supporting Alt 3, maybe most of companies did not consider that one special CORESET need to be reserved for beam recovery. In our view Alt3 should be further studied considering potential limitations.  Furthermore, when UE is connected with two TRPs, the two TCI states configured by NW could change frequently due to the mobility or rotation. In the case of two TCI states are both updated, at least two DCIs and two MAC CEs are needed for Alt3, while only one DCI and one MAC CE are needed for Alt1-3 which has lower latency and overhead.  Hence, we suggest following revision of proposal3:  ***Proposal 3*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, ~~at least support~~ down-select between Alt1-3 and Alt3 (two SS sets associated with corresponding CORESETs)***  ***FFS: whether or how to extend the limitation of CORESET number for Alt3.*** |
| MediaTek | Support FL’s proposal. We have the same view as FL. CORESET can be reused for other SS set which is targeted for S-TRP. We don’t see any issues regarding the number of CORESETs. As commented by OPPO, please remove “at least”. We don’t need to support more than one scheme. |
| Intel | @LG: for Alt-1-3 each of the candidates of the two SS-sets fully overlap as the hashing function is the same for the two SS-sets in the same slot. This implies strict TDM multiplexing of mTRP repetitions.  We are not sure why CORESET#0 and the other non-BFR CORESET cannot be used for Alt-3 repetitions – this is the same assumption for MDCI – MTRP with number of CORESET=3, isn’t it ? |
| Futurewei | Support the FL’s proposal.  Increasing the number of CORESETs to up to 5 can be considered. This might slightly increase signaling overhead and complexity, but it is a much cleaner solution than others with significant changes of the standards. In addition, the most crucial factor for complexity/capability here is not the number of CORESETs but the number of BDs; as long as the number of BDs is within a limit, up to 5 CORESETs would not cause any complexity/capability issue. |
| FL Summary | It seems that Apple, LG, vivo and CATT have concerns with the proposal while other companies support or can accept the proposal.  @ vivo: From FL point of view, a decision is needed in this meeting. All the aspects have been discussed extensively. If we need another down-selection in the next meeting, all the other details would be pending on that decision.  @ Apple, LG, vivo, CATT: It is not clear how Alt1-3 can work with FDM. As intel mentioned, PDCCH candidates fully overlap across both SS sets if the monitoring occasions are the same. Regarding the issue of CORESET shortage in the Pcell, CORESET0 is not precluded to be used as one of the two CORESETs in Alt3. I will add an FFS as below to address your concerns regarding number of CORESETs. Please note that progress in the next meeting becomes difficult without an agreement on the alternatives.  @ SS, OPPO, MTK: My thinking is that we can keep “at least” to not completely close the door to other additional Alts. At the end, if companies do not agree with additional Alts, the details will be discussed only for Alt3. If we remove “at least”, other companies may not accept it.  ***Updated FL Proposal 3*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, at least support Alt3 (two SS sets associated with corresponding CORESETs).***   * ***FFS: Whether additional CORESET(s) (more than 3 CORESETs) are needed for Pcell when CORESETPoolIndex value is not configured.*** |

## **BD Limit**

When 2 PDCCH candidates are linked, how they should be counted toward the BD (/ CCE) limit should be discussed. Here, we only focus on Option 2 + Case 1, which is agreed. The following is a summary of previous discussions with some additions:

* For CCE limit, Rel. 15/16 procedures are enough as the CCEs of the two PDCCH candidates can be considered separately for channel estimation complexity purpose.
* For BD limit:
  + With respect to the complexity associated with RE de-mapping / demodulation, 2 units are required
  + With respect to the complexity associated with decoding:
    - >= 1 unit (Assumption 1): UE only decodes the combined candidate without decoding individual PDCCH candidates (the reason for >= is that soft-combining may have additional complexity associated with storing)
      * In this case, blockage may impact the performance (no separate decoding)
      * In this case, it may be implied that gNB has to always transmit the DCI in both PDCCH candidates (i.e. cannot choose only one)
    - 2 units (Assumption 2): UE decodes individual PDCCH candidates
      * Soft-combining not taken into account for BD
    - >= 2 units (Assumption 3): UE decodes the first PDCCH candidate, UE also decodes the combined candidate
      * In this case, if the first PDCCH candidate is blocked (either due to PDCCH blocking or due to blockage), the second decoding may be impacted (in addition to the first decoding)
      * In this case, it may be implied that gNB cannot choose to transmit the DCI only in the second PDCCH candidate
    - >=3 units (Assumption 4): UE decodes each PDCCH candidate individually, and also decodes the combined candidate
  + Overall, 2 BDs or 3 BDs can be considered given the above, which may depend on UE capability and/or configuration. Given this, it should be discussed whether “soft-combining” can be transparent to the spec.

Please comment how the issue of “how the two PDCCH candidates are counted toward the BD limits” should be addressed given the summary above. FL proposal may be drafted (to at least list some possibilities for down-selection) based on the inputs:

|  |  |
| --- | --- |
| Company | Comments |
| LG | We think all assumptions should be considered. From my understanding, UE reports one of assumptions as capability and gNB indicates how to count BD depending on the capability. For example, if UE reports assumption 4 capability, gNB can indicate one of assumption 1, 2, 4 (since assumption 1, 2 are subset of assumption 4) to determine how to count # of BD. If gNB indicates assumption 1, it reduces required # of BD but cannot achieve diversity in blockage. In contrast, if gNB indicates assumption 4, it increases required # of BD but can achieve diversity in blockage. Similarly if UE reports assumption 3 capability, gNB can indicate one of assumption 1, 3 (since assumption 1 is subset of assumption 3). Also, UE should be able to report assumption 2 capability considering implementation burden, and then it becomes repetition without soft combining, achieving the same performance as Option 3.  Since # of BD depends on whether soft combining is applied as we explained above, in our view, soft combining is not spec transparent. |
| Apple | We are not sure whether no separate decoding would have impact on performance for assumption 1.  Regarding the gNB behavior, if the repetition scheme is enabled, we failed to see the motivation for gNB not to transmit some repetitions. If gNB decide not to use repetition-based scheme, it can select a SS without repetition-based scheme to transmit PDCCH.  In general, we acknowledge that whether to apply soft combining or not may not be transparent, but we are not sure whether some of the 4 BD assumptions are necessary. Especially for assumption 1, 3, and 4, we are not sure how much performance gap would be observed. |
| CMCC | Soft-combining should not be transparent to spec, the UE behavior for assumptions 1/2/3/4 should be known by gNB to align the consistent understanding on BD limit. |
| Spreadtrum | For assumption 1/3/4, BD limit could be further elaborated with max restriction as follows.   * <2 unit and >= 1 unit (Assumption 1) * <3 unit and >= 2 units (Assumption 3) * <4 unit and >=3 units (Assumption 4)   From high level perspective, soft combing seems not to be transparent considering the significant difference of BD limit among the four assumptions if supported. However, for assumption 1/3/4, the performance gap among them is not clear. If there is little or no performance gap between assumption 3/4 and assumption 1, only assumption 1 and 2 could be considered to support. Then soft combing to be transparent to spec may be OK, for little of difference of BD limit between assumption 1 and 2, and limited PDCCH repetition association configuration. Thus, we suggest to evaluate and down-select assumptions firstly, then to discussion whether soft combing is transparent to spec. |
| ZTE | Our understanding for Option 2 + case 1 is, gNB should always transmit two associated PDCCH candidates. If gNB can transmit only one of two, does UE still do rate matching around both PDCCH candidates if overlapping happens between PDCCH and PDSCH ? If yes, resource waste may be caused. If not, how could UE know which PDCCH is not transmitted.  Assumption 2 should be deprioritized since there is no performance gain based on companies simulation results.  Assumption 3 is a compromised solution between Assumption 2 and 4. The benefit is not clear.  Thus, we propose to focus on assumption 1 and assumption 4, and further do simulation to analyze whether blockage impacts the performance (no separate decoding) for assumption 1. In our view, if one PDCCH is blocked, the receive power of this PDCCH will be very low. Even UE does soft combining, the low power PDCCH will not affect the final combining results too much. So assumption 4 may not be needed. |
| Xiaomi | We think soft-combining should not be transparent to spec. and we prefer assumption 1 that UE only decodes the combined candidate without decoding individual PDCCH candidates. And with this assumption, gNB can select other SS without repetition-based scheme to transmit PDCCH by one TRP. |
| OPPO | From UE perspective, Assumption 1 should be supported in Rel-17. Other assumptions can be down-selected based on further simulation results. We are also fine with Spreadtrum’s clarification on the upper bound. |
| Samsung | As other companies argue, we also think that soft combining cannot be supported spec-transparent manner. Also, since soft combining always has better performance rather than selection, we think that performance gain based on assumption 3 and 4 may be marginal. Hence, if we define BD counting assumption, some assumptions in above seem to be deleted so it can be enough for UE to report whether soft combining is supported or not. |
| Huawei, HiSilicon | Support to further discuss the above assumptions, no need to preclude any of them at this stage. |
| NTT Docomo | Regarding the assumptions, we agree with Spreadtrum and ZTE that performance can be further evaluated to decide from assumption1/2/3/4. In addition, in our view, for UE that supports PDCCH repetition, there should be a default decoding capability. Then whether other capability is needed can be further considered.  Regarding whether soft combining can be transparent, we think it depends on which assumption we select.  When counting toward BD limit, if we assume different number of units for repetition with and without soft combining, it cannot be transparent.  If we assume same number of units e.g. 2 for both repetition with and without soft combining, soft combining transparent in spec. may be possible. |
| Fujitsu | We share the same understanding as LG. Soft combining should not be spec transparent. |
| Futurewei | We suggest to consider two types of typical cases:   * Worst case or upper bound BDs, which is Assumption 4 and may correspond to a non-optimized implementation; * Best case or lower bound BDs, which relies on the UE to smartly choose one or two PDCCH candidates to decode (such as based on the SINR estimates on the DMRS). For example, if one seems to be blocked, the UE uses only the other to decode, otherwise both are used to decode. Then one BD is sufficient.   So it seems at least there is some implementation that the conventional BD counts can still be used, i.e., one BD per one DCI. There may not be any need to standardize additional UE behavior. The UE implementation can feel free to choose between a non-optimized approach which relies on more BDs and an optimized approach with fewer BDs based on side information from SINR.  We are also open to other views.  We are not sure why >3 is included in Assumption 4. To us the maximum can be 3. Please clarify. |
| Lenovo/ Motorola Mobility | We think all 4 assumptions can be considered based on UE capability and/or configuration since some flexibility is required at both UE’s and gNB’s side. For assumption 1, it may be used for case without blocking and has the benefit of low decoding complexity. |
| QC | While the details of how UE considers combining can be spec-transparent, “how to count toward the BD limit” is no transparent. The minimum number of BDs needed is 2 (due to two separate RE demapping / demodulation). We need to also agree on other values. For example, with assumption 4, at least 3 BDs are needed. Then, UE can indicate which assumptions / how many BDs it requires for this purpose, and network can configure accordingly.  To answer ZTE: Network can have the choice of transmitting both or only one of them. If DCIs overlap with PDSCH, then UE rate matches around both anyway (no ambiguity). There is no issue of resource waste as the candidate that is not transmitted can be used for other UEs. |
| MediaTek | We don’t support assumption 1 and 4. Assumption 1 may be used for FDM case, but it should be up to UE implementation in a spec transparent way. Even for this case, we should use 2 BDs. For assumption 4, if PDCCH candidate is repeated, the UE doesn’t have to decode it separately and also jointly. Depending on UE capability, we can use assumption 2 for selection decoding and use assumption 3 for soft combining. We think this issue can be quite controversial. We recommend to postpone the detailed discussion on this issue at the next meeting in order to give companies more time to analyze this internally. |
| Intel | Agree with CCE counting bullet that existing rules can be used.  For BD it is easier to discuss after selection of Alt-3/Alt-1-2/Alt-1-3, but our point of view is motivated by Alt-3. In this case, following Rel-15 procedure, UE tries to decode candidates from 2 SS-sets anyways, so Assumption-1 is not considered, but Assumptions 2-3-4 are all okay to consider for further discussion. In short, we do not support Assumption-1 but okay to discuss assumptions 2, 3, 4. |
| Fraunhofer | UE’s capability of soft-combining and/or the transmission of the PDCCH with the restrictions for soft-combining cannot be spec. transparent.  In our view, one of the above BD assumptions will be supported by the UE as a capability. From our simulation results, selection decoding performs worse than soft-combining and hybrid decoding (one PDCCH candidate decoded, followed by soft-combining if the first one fails). Therefore, assumptions 1 and 3 shall be considered further. Assumption 4 has high UE complexity and hence need not be considered further. |
| InterDigital | We do not support assumptions 1 and 4. Our suggestion is to further study decoding scenarios based on assumptions 2 and 3.  Also, we agree with other companies that soft-combining should not be spec transparent. |
| Ericsson | We think the main motivation for enhancing PDCCH with multiple TRPs is to deal with channel blocking in FR2. Either decoding individual PDCCH candidates (Assumption 2) or the combined candidate (Assumption 1) are applicable in our view. At least decoding individual PDCCH candidates should be supported. Decoding the combined candidate with soft combining can be an extra UE feature.  Furthermore, as commented by Docomo, if 2 BDs are assumed for both decoding individual PDCCH candidates and decoding combined PDCCH candidates, soft- combining can be spec transparent as well. |
| vivo | We prefer Assumption 1 as UE default capability in Rel17.  With option2+case1, we do not understand why UE would decode individual PDCCH candidates and which needs at least two polar decoding, in our view, Assumption1 is enough and soft bits combining is just a simple addition operation, which has lowest complexity comparing with other assumptions.  Furthermore, soft bits combining is an algorithm with SNR weighting, even though there is a case that one of PDCCH candidate is blocked (either due to PDCCH blocking or due to blockage), the SNR weighting for soft bits of blocked candidate is very small, which has little impact to soft bits of another PDCCH candidate, the performance of soft bits combining is also guaranteed.  Of course, for PDCCH blocking (not about blockage of wireless channel), a simple rule of cancellation of all PDCCH candidates for repetition when one of them is blocked due to the blocking of PDCCH resource allocation (not blockage of wireless channel) can be considered. Anyway, overbooking rule has dependency with the problem of BD limit here, and may depend on one SS or two SSs selected (e.g. Alt1-2/1-2/2/3), hence discussion of overbooking should also be taken together. |
| Nokia/NSB | We think that UE assumptions may vary for different UEs, and the same UE could play already with the BG limits if they wish to use more benefits through PDCCH repetitions. For example, the same UE may consider decoding of PDCCH candidates with different assumptions.  If the BD limits to be considered together with the UE assumptions on decoding, it makes sense that we discuss that under UE capability discussion. For example, the UE may report that for PDCCH repetition scheme, the counting of BD limits shall consider 1/2/3 times for a PDCCH candidates that are getting repeated. |

**4.2.1 FL Update**

The company views are summarized below:

* Should be further discussed: Apple, Huawei, HiSilicon, NTT Docomo, Nokia/NSB
* All assumptions should be considered: LG, CMCC, Lenovo/Motorola Mobility
* Assumptions 1 and 4: ZTE, Futurewei
* Assumptions 1 and 2: Spreadtrum, Ericsson
* Assumptions 2 and 3: MediaTek, InterDigital
* Assumptions 1 and 3: Fraunhofer
* Assumption 1 only: Xiaomi, vivo
* At least Assumption 1: OPPO (Potential down-selection on others depends on further discussion/simulation)
* Assumptions 2, 3, 4: Intel
* UE only reports if soft-combining is supported: Samsung
* UE reports whether 2 or 3 BDs should be counted: QC

@ Futurewei: The reason for >=3 in Assumption 4 (or >=1 and >=2 in Assumptions 1 and 2) is the potential additional complexity associated with storing and then soft combining, which occurs before decoding.

Regarding CCE limit, there seem to be common understanding. For BD limit, the views are very diverse at this point. It is clear that further discussions (and perhaps evaluations) are needed. The following proposal can be considered mainly for further study on the BD limit:

***FL Proposal 4*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, CCEs of the two PDCCH candidates are counted separately following Rel. 15/16 procedures. Further study the BD limit by considering the following***

* ***With respect to the complexity associated with RE de-mapping / demodulation, 2 units are required***
* ***With respect to the complexity associated with decoding, the following assumptions can be further discussed:***
  + ***Assumption 1: UE only decodes the combined candidate without decoding individual PDCCH candidates***
  + ***Assumption 2: UE decodes individual PDCCH candidates***
  + ***Assumption 3: UE decodes the first PDCCH candidate and the combined candidate***
  + ***Assumption 4: UE decodes each PDCCH candidate individually, and also decodes the combined candidate***
* ***Note: The Assumptions 1-4 are for discussion purpose only, and they may or may not have specification impact.***

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | Support FL proposal. |
| Nokia/NSB | We are not fully sure the need of the above proposal. Anyways, we have not objections.  May be on more assumption could be added. It is hard to predict that UE will follow same mechanism when decoding a PDCCH. In that sense, we might not able to could number of BDs based on a fixed assumption. We should let UE to report what would be the impact on BD limits and how many BD that network shall count for PDCCH repetition cases.  ***FL Proposal 4*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, CCEs of the two PDCCH candidates are counted separately following Rel. 15/16 procedures. Further study the BD limit by considering the following***   * ***With respect to the complexity associated with RE de-mapping / demodulation, 2 units are required*** * ***With respect to the complexity associated with decoding, the following assumptions can be further discussed:***   + ***Assumption 1: UE only decodes the combined candidate without decoding individual PDCCH candidates***   + ***Assumption 2: UE decodes individual PDCCH candidates***   + ***Assumption 3: UE decodes the first PDCCH candidate and the combined candidate***   + ***Assumption 4: UE decodes each PDCCH candidate individually, and also decodes the combined candidate***   + ***Assumption 5: The UE may consider any of the above assumption when decoding (not a fixed assumption), but BD limit considerations is only based on the reported complexity (e.g. expected long term average on the increase of BDs).*** * ***Note: The Assumptions 1-4 are for discussion purpose only, and they may or may not have specification impact.*** |
| Apple | Support the proposal |
| NTT Docomo | For the CCE part, we agree that the number of CCEs is independent for each two PDCCH candidates. But in our view, how to count CCEs of the two PDCCH candidates toward maximum number in PDCCH overbooking procedure (separately following Rel-15/16 procedure or together) can be further studied.  Regarding the four assumptions, do we discuss the case of repetitions within a slot only or also the case of repetitions across slots? We have not discussed it yet, but it is better to clarify it. Because for TDM repetition case (especially for inter-slot repetition), assumption1 will cause obvious latency.  On the other hand, BD is counted per slot. Hence, for the case of repetitions within a slot or the case of repetitions across slots, we may discuss separately on how to count BD. |
| Huawei, HiSilicon | We are fine to further discuss/clarify the UE behaviors according to the assumptions. Regarding to Nokia’s proposal of assumptions 5 that “***The UE may consider any of the above assumption when decoding***”, we think the UE behavior should be subject to gNB configuration, and so that gNB can perform an efficient scheduling. |
| OPPO | Ok. Support to further discuss the different assumptions of BD limits. |
| LG | Support |
| ZTE | Support.  The assumption 5 proposed by Nokia seem not a parallel potion with others. |
| CATT | Support this proposal. Assumption 1 and 2 are acceptable to us. |
| vivo | Support the proposal.  We also agree with DOCOMO’s comment on how to count BD. Regarding the BD limit, we think it is better to be constrained per monitoring span or per slot. If two linked PDCCH candidates cross span or slot, the BD limit should recount and Assumption1 doesn’t work.  We suggest add the following note:  ***Note: the BD /CCE limit here is counted based one the configuration of PDCCH monitoring capability (e.g. per slot or per span).*** |
| MediaTek | We can accept the proposal since we need more discussion to align understanding of BD decoding at the UE.  Regarding assumption 1, the UE is performing BD per MO/SS set. If two PDCCHs are in the different MO/SS set, we cannot just assume assumption 1. Even for intra-slot repetition, if two SS sets are TDMed, then the UE is trying to decode the first candidate as in assumption 3. If it is successful, the UE may stop decoding of the second to further save the power (This is up to UE implementation). If it is failed, then apply soft combining and proceed the second decoding. We think assumption 1 can only be used in FDM. But the spec cannot force the UE to do it.  We support with the Note suggested by vivo. |
| Intel | yes, better to discuss this further. The first sub-bullet is a little premature to agree for us. OK with 2nd and 3rd sub-bullets. Note from Vivo is also okay for us. |
| Futurewei | Support |
| FL Summary | @ Nokia, vivo: Your suggestions are taken into account below, also considering Huawei / ZTE’s comments.  @ DCM: The intention is to discuss overbooking after the impact of BD limit becomes more clear. If at the end, we conclude that only 2 BDs are needed, overbooking may not need spec change. Regarding inter or intra-slot, we can discuss this in more details in the next meeting (not just for the purpose of BD counting, but in general). Note that even for intra-slot case, the BD/CCE limits can be per span.  @ Intel: For the first sub-bullet, it seems that separate RE mapping and demodulation is required. If there is no concern, I suggest to consider this aspect for further discussions regarding the BD limit.  ***FL Proposal 4*: *For PDCCH reliability enhancements with non-SFN schemes and Option 2 + Case 1, CCEs of the two PDCCH candidates are counted separately following Rel. 15/16 procedures. Further study the BD limit by considering the following***   * ***With respect to the complexity associated with RE de-mapping / demodulation, 2 units are required*** * ***With respect to the complexity associated with decoding, the following assumptions can be further discussed:***   + ***Assumption 1: UE only decodes the combined candidate without decoding individual PDCCH candidates***   + ***Assumption 2: UE decodes individual PDCCH candidates***   + ***Assumption 3: UE decodes the first PDCCH candidate and the combined candidate***   + ***Assumption 4: UE decodes each PDCCH candidate individually, and also decodes the combined candidate*** * ***Note 1: The Assumptions 1-4 are for discussion purpose only, and they may or may not have specification impact.***   + ***FFS: The relationship between UE capability, RRC configuration, and the BD limit, and whether the Assumptions 1-4 are relevant for this purpose.*** * ***Note 2: the BD /CCE limit here is counted based one the configuration of PDCCH monitoring capability (e.g. per slot or per span).*** |

## **DCI Format 2\_x**

In the second agreement for non-SFN scheme, we have “*whether and how to support for DCI format 2\_x*”. It would be good to reach a conclusion on the “whether” part so that the scope of discussions for the next meeting becomes clear.

Please comment if you think all or some of the DCI formats 2\_x should be considered in the mTRP PDCCH enhancement framework (at least for the combination option 2 + case 1, which is agreed) or if they should be excluded:

|  |  |
| --- | --- |
| Company | Comments |
| LG | It depends on DCI format. For example, we don’t see issue in case of intra-slot DCI repetition with 2-0, since it indicates SF in slot level granularity. In the other hand, other DCI formats have symbol level granularity, it causes confusion to STRP UE. |
| Apple | Some clarification may be necessary to preclude DCI format 2\_x. |
| ZTE | We don’t think the MTRP solution is applicable for DCI 2\_x. That’s because common group DCI is for multiple UEs, however, different Ues may have different coordinated TRPs, the second TCI is hard to be shared for the multiple coordinated TRPs of different Ues. In addition, common group DCI is usually transmitted by wide beam width, the blockage probability is low, no need to use PDCCH repetition with multi-beams.  Furthermore, enhancement for common group DCI has been considered in NR coverage agenda, the following agreement has been achieved. So we don’t think the same discussion should be repeated in MIMO.  Agreements: Capture the followings into the TR  Broadcast PDCCH repetition was studied. Potential specification impacts include PDCCH repetition configuration. |
| Xiaomi | Share same view as Apple |
| OPPO | DCI format 2-x are group-common DCIs. Meanwhile, m-TRP transmission are UE-specifically configured. Moreover, as ZTE mentioned, it is very hard for a group of UE to share the same set of two active TCI states used for DCI format 2-x. Thus, the motivation and benefits for the combination of these two features need further justification. |
| Huawei, HiSilicon | The support of DCI format 2\_x can be further discussed. |
| NTT Docomo | We agree with ZTE that multiple TCIs are hard to be shared by a group of Ues. Thus, we think MTRP for DCI format 2\_x can be excluded. |
| Fujitsu | Further discussion is necessary for the support of DCI format 2\_x. |
| Futurewei | We think GC DCI 2\_x can still be supported in M-TRP. Even if some of the Ues associated with the DCI do not support M-TRP (due to UE capability or configuration), the M-TRP PDCCH transmissions can still benefit those M-TRP Ues. Some blocks within the GC DCI may turn out to be unused but that does not seem to cause any problems. It should benefit the system if M-TRP GC DCI is an option for the network to choose, at least for FR1. |
| Lenovo/ Motorola Mobility | PDCCH for DCI format 2\_x transmitted from multiple TRPs can bring spatial diversity gain. Thus, more discussion and clarification (e.g. DCI format) can be made for DCI format 2\_x. |
| QC | We think DCI format 2-x are important to be supported. For example, the reliability of SFI or UL cancelation is very important in URLLC scenarios.  Also, it should be noted that we can have multiple groups of Ues (based on RNTI) for the Ues in similar conditions. Group-common DCI does not mean that they have to be common across the whole universe of Ues. The structure of GC-DCI is very flexible in terms of how network wants to “group” the Ues.  Comment to ZTE: Broadcast DCI is not the same as DCI format 2-x. Broadcast DCI in coverage enhancement are mostly about DCI scheduling SIB1. Furthermore, the motivation here is reliability and not coverage enhancement. |
| MediaTek | We are fine that DCI format 2\_x can be further discussed for MTRP PDCCH enhancement. |
| Convida Wireless | We didn’t see a strong reason to preclude DCI format 2\_x, since its use and configuration is up to the network. We can discuss further. |
| Intel | We think we should support DCI format 2-x for URLLC. |
| InterDigital | We think further discussions may be needed on the benefits of supporting DCI formats 2\_x.  FR1 may have a higher likelihood of finding group of Ues sharing the same TCI, however at the same time, beams may not change very often so it’s not clear if the signaling overhead saved by using group common DCI formats would be significant.  In FR2, due to narrow beams, there may be a lower likelihood of finding Ues sharing similar TCIs. |
| Ericsson | So far, only UE-specific transmission has been discussed for PDSCH and PDCCH enhancement with multi-TRP. So we think we should prioritize use cases with UE specific DCIs for now with regards to PDCCH multi-TRP enhancements. Whether PDCCH multi-TRP enhancements are to be extended to DCI format 2-x can be discussed later after completing high priority issues. |
| Vivo | Regarding DCI format 2\_x, which is applicable to indications of information for more than one Ues, for DCI format 2-x in option2 and case1, these Ues must be associated with two TCI states concurrently. In real implementation (example shown in the figure), probability of grouping is low, and it is UE-specific SS rather than common SS which results in that NW occupies more PDCCH resource to transmit DCI format 2\_x for each Ues.    So we do not think combination of option2 and case1 is efficient for DCI format 2-x, however, the objective of PDCCH enhancement in Rel17 is mainly to improve the performance of M-TRP/panel, especially to cope with the blockages in FR2, all of the DCI formats should be enhanced. We expect other combinations can be taken into account, for instance, combination of option3 (multi chance) and Case2 (implicit linkage) may be a good scheme for DCI format 2-x, which can be further discussed. |
| Nokia/NSB | Group based DCI 2\_x are not critical for typical operation. We do not think this should be the main discussion here. |

**4.3.1 FL Update**

The following summarizes companies view:

* DCI formats 2\_x should not be precluded: LG (depending on each format), Apple, Xiaomi, Futurewei, Lenovo/ Motorola Mobility, QC, Convida Wireless, Intel, vivo
  + Further discuss: Huawei / HiSilicon, Fujitsu, MediaTek, InterDigital
  + Lower priority: Ericsson
* DCI format 2\_x should be precluded: ZTE, OPPO, NTT Docomo, Nokia/NSB

The majority view is that the enhancements related to DCI formats 2\_x should not be precluded as the reliability enhancement can be relevant for URLLC. At the same time, more discussions may be required on a case-by-base basis. There are also comments regarding the priority of group-common DCIs. From FL side, it is reasonable to assume higher priority for UE specific DCIs. In order to clarify the scope and considering that more important issues should be discussed first, the following proposal can be considered:

***Updated FL Proposal 5: 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.***

|  |  |
| --- | --- |
| Company | Comments |
| Samsung | Support FL proposal. |
| Nokia/NSB | Not objecting the majority view. |
| Apple | Support the proposal |
| NTT Docomo | Support FL proposal. |
| Huawei, HiSilicon | We are fine with the FL proposal. |
| OPPO | We are still not convinced with the benefits of potential enhancement. In order to make progress, we can compromise to support the proposal with the following modification (Highlighted by Yellow):  ***Updated FL Proposal 5: Further discussion of 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.*** |
| LG | Support FL proposal. |
| ZTE | Support OPPO’s update. FL proposal is also acceptable for us. |
| CATT | Support this proposal. |
| vivo | Support FL proposal. |
| MediaTek | Support FL proposal. |
| Intel | We are okay with this. |
| Futurewei | Support |
| FL Summary | Seems that most companies are ok with the proposal.  @ OPPO: The intention of the proposal is to say that group-common DCIs are in scope, but they have lower priority, and if enhancements are required, we can discuss case-by-case. I suggest to keep the original proposal as the yellow addition may imply that we need to discuss again whether DCI formats 2\_x are in scope or not.  No change is made to the FL proposal 5. |

# **Detailed Proposals / Observations**

|  |  |
| --- | --- |
| FUTUREWEI | * Support at least Alt 3 (Two SS sets associated with corresponding CORESETs) and Option 2 (repetition) * At least TDM and/or FDM and/or SFN for FR1, and FFS one FFT vs two FFT; TDM for FR2 * Support Case 1 |
| Huawei, HiSilicon | * Support Option 2 (repetition) for multi-TRP PDCCH transmission * Case 1 (explicit linkage) * Support both TDM and FDM * For Option 2, slightly prefer Alt 3 or Alt 1-3 to enable two TCI states for PDCCH |
| InterDigital, Inc. | Alt. 1-1 is not supported |
| vivo | Support SFN, TDM and combination of the two for multi-TRP PDCCH enhancement  Support Alt1 for association of CORESETs and search space for PDCCH reliability enhancement:   * + adopt Alt1-1 to support SFN and SFN+TDM scheme.   + adopt Alt1-3 to support explicitly and implicitly linked PDCCH chances/candidates |
| ZTE | * The following sub-schemes for scheme 1 (No repetition) achieve similar functionality and UE complexity   + Scheme 1-1: SFN   + Scheme 1-2 ( Option1 + Alt1-1 + FDM), i.e. one PDCCH resource is split into two frequency parts which correspond to different TCI states   + Scheme 1-3 ( Option1 + Alt1-1 + TDM), i.e. one PDCCH resource is split into two sets of OFDM symbols which correspond to different TCI states * For a UE with capability of soft combining, the following sub-schemes of scheme 2 (repetition, UE can do soft combining) achieve similar functionality and UE complexity   + Scheme 2-1 ( Option2 + Alt1-2 + Case1) , i.e. two PDCCH candidates of one SS are explicitly linked   + Scheme 2-2 ( Option2 + Alt1-3 + Case1) , i.e. two PDCCH candidates of two SS within one CORESET are explicitly linked   + Scheme 2-3 ( Option2 + Alt2 + Case1) , i.e. one SS is associated with two CORESETs   + Scheme 2-4 ( Option2 + Alt3 + Case1) , i.e. two SS associated with corresponding CORESETs * Scheme 3, i.e. multi-chance PDCCH transmission has very good flexibility and backward compatibility with Rel-15/16   + Scheme 3: ( Option 3 + Alt3 + Case 2), separate DCIs from two SS associated with corresponding CORESETs can schedule the same PDSCH /PUSCH /RS/TB/etc. or result in the same outcome   + Support two DCIs in the same slot or different slots. An additional slot offset between one DCI and the correspondingly scheduling signaling is supported.   + Two DCIs can also trigger independent signaling as Rel-16/15 * Support scheme 1-1(SFN) and scheme 3(multi-chance) for UE with and without two receive beams capability respectively |
| Fujitsu | * Support both the TDM scheme and FDM scheme * At least supports Case 1 |
| TCL communication | * For one CORESET with two active TCI states, Alt 1-3 is preferred |
| CATT | * TDM, FDM and SDM (SFN) based multiplexing schemes can be supported * The following detailed schemes can be considered for TDM and FDM,   + Intra-CORESET multiplexing   + Intra-slot multiplexing with different CORESETs   + Inter-slot multiplexing with the same CORESET index in each slot   + Inter-slot multiplexing with different CORESET indexes in each slot * The following combinations for non-SFN schemes can be supported,   + Alt. 1-1 + Option 1   + Alt. 1-2, 1-3, 2, 3 + Option 2/3 * The following linkages among multiple PDCCH candidates can be considered to reduce complexity of blind detection.   + Linkage 1: Indexes of linked PDCCH candidates or SS sets or CORESETs can be configured or predefined.   + Linkage 2: Time and frequency resources of one DCI can be indicated by other DCI.   + Linkage 3: Association of TCI states of multiple repetitions can be configured, predefined or indicated by one DCI.   + Linkage 4: Aggregation levels of linked PDCCH candidates can be configured or predefined. * Transmission schemes which require soft combining or independent decoding at the receiver can both be considered to enhance PDCCH reliability |
| CMCC | * Support TDM, FDM, and SFN schemes for different UE capabilities and different use cases * For SFN scheme, the DMRS of PDCCH can be associated with two TCI state indices, where two TCI states are indicated by MAC CE * Support repetition scheme (Option 2) for PDCCH from different TRPs to improve PDCCH reliability * Support 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) and Alt 3 (Two SS sets associated with corresponding CORESETs) for PDCCH from different TRPs to improve PDCCH reliability * Support explicit linkage (case 1) between PDCCH candidates from different TRPs |
| Samsung | * Support both Option 2 and Option 3 for multi-TRP PDCCH repetition. Careful consideration of UE implementation complexity of Option 2 (repetition) is needed * Support TDM based PDCCH repetition as a starting point * On resource configuration for multi-TRP based PDCCH repetition, support Alt3 * *For multi-chance, support implicit linkage based on the contents between each repeated DCI contents* * Support modified counting rule and the maximum limit for the number of monitored PDCCH candidates and non-overlapped CCEs based on a manner of PDCCH enhancement: no repetition, repetition, multi-chance * Support modified overbooking rule enabling to select the subset of PDCCH candidates and CCEs in a common or UE-specific search space sets which include repeated PDCCH candidates |
| OPPO | * Support one CORESET with two active TCI states for PDCCH enhancement based on multi-TRP * Repetition(option 2) is preferred for non-SFN based mTRP PDCCH reliability enhancement * For PDCCH enhancement, inter-slot TDM transmission without repetition is not supported * It is hard to support FDM for no repetition with aggregation level 1 under some REG bundle size and duration of CORESET * How to ensure same time and frequency domain resource between 2 SS sets needs further study for Alt 2 and Alt 3 * Support one or more multiplexing schemes (TDM, FDM, SFN and combined scheme) based on the framework of Rel-15/16 as much as possible.   + TDM has higher priority than FDM considering lower reception requirement.   + FDM and SFN are workable only for advanced UE with two simultaneous RX beam in FR2 * Support Alt 1-1, i.e., one PDCCH candidate is associated with both TCI states of the CORESET * Support explicit linkage between PDCCH candidates if Alt 1-2/1-3/2/3 is agreed |
| Sony | * Support both Alt2(One SS set associated with two different CORESETs) and Alt3(Two SS sets associated with corresponding CORESETs) * For TDM scheme, specify the UE capability whether the UE can monitor simultaneously two CORESETs using different antenna panels in UE side * Specify the gap between two different PDCCH from different TRPs for the UE without simultaneous reception capability |
| Apple Inc. | * Compared to option 2 (repetition) and option 3 (multi-chance), option 1 (no repetition) is preferred, where REG bundle level beam cycling is supported. * Support Alt1 (One CORESET with two active TCI states). |
| LG Electronics | * TDM based MTRP PDCCH scheme should be supported with priority and FDM based scheme or SFN based enhancement can be considered additionally * Support 2 TCI states configuration/activation for a single CORESET for MTRP PDCCH scheme. * For multi-chance PDCCH scheme, Option 3 can be considered with priority if additional gain from soft combining is not fully justified, taking into account UE complexity and specification impact. * For single-chance PDCCH scheme, FDM based Option 1 and SFN based enhancement can be considered |
| Fraunhofer IIS, Fraunhofer HHI | * For Alt 1-2/1-3/2/3, two (or more) PDCCH candidates are explicitly linked together (UE knows the linking before decoding). * The decoding method employed and the corresponding number BD attempts for a pair of linked PDCCH candidates to be calculated towards the BD limit is as follows:   + Soft-combining: 1   + Hybrid decoding or selection decoding: 2 * Consider one of the following transmission schemes for PDCCH reliability enhancement   + Alt 2: One SS set associated with two different CORESETs   + Alt 3: Two SS sets associated with corresponding CORESETs * Use MAC-CE for the signalling of the association of the SS set with one or more CORESETs for Alt-2 or the association between two SS sets for Alt-3. * FDM is preferred to TDM for PDCCH repetition or multi-chance PDCCH |
| Nokia, Nokia Shanghai Bell | * Consider Alt 1-1 + option 1 + FDM combination with higher priority * Support Alt 1-2 + option 2 + TDM combination with the following considerations,   + Support activating two TCI states per CORESET   + Activated TCI states of the CORESET and monitoring occasions defined by the SSSs to that CORESET shall be mapped with a predefined rule or configuration by considering a fixed period * Alt 1-3 related combinations shall not be considered further * For PDCCH reliability enhancement, Alt 2 related combinations shall not be considered further * Consider Alt 3 + option 2 + TDM combination with higher priority for down selection with other combinations.   + If supported, further study mechanism to enable linking between SS sets such that soft combining can be supported at the UE |
| Lenovo, Motorola Mobility | * TDM schemes can be considered as the baseline for PDCCH enhancement   + For FR2, FDM/SFN schemes can be considered only for UE with high capability * Configurations:   + Configuration Alt.1-1 can be used for FDM/SFN   + Configuration Alt.1-2/Alt.1-3 can be used for TDM/FDM   + Configuration Alt.1-3 can provide flexible parameter configuration for each search space set associated with one TCI state of the CORESET with tradeoff of increasing of search space set number   + For configuration Alt. 2, schemes for REG to CCE mapping and CCEs to candidate mapping based on multiple CORESETs need being further studied   + For configuration Alt. 3, it can be used for TDM/FDM based enhanced PDCCH transmission with the most flexible configuration and can be easily combined with repetition scheme to meet higher reliability requirement * Support Option 3 * One-one mapping may be used for determining linked candidates from different candidate set with different TCI states * Use sequence number to identify the DCIs serving the same purpose * If multiple DCIs serving the same purpose can be sent out at different time, introduce in each DCI a timing offset to the time the last DCI is sent to avoid timing ambiguity |
| NEC | * Two PDCCH candidates each with one TCI state should be supported, and option 2 (repetition) should be supported * Two PDCCH candidates are explicitly linked together * Same payload for PDCCH repetitions should be further studied, at least including scheduling offset and DAI field, and explicit linking between PDCCH candidates can be utilized |
| MediaTek Inc. | * Support Alt 3 as the first preference. Also, we can support Alt 1-2 with multiple monitoring occasions and Alt 1-3 as the second preference * TDM should be prioritized in order to relax the UE complexity.   + Both intra-slot and inter-slot TDM * Support Option 2 (Repetition) and Case 1 (Explicit linkage) to use soft combining |
| Intel Corporation | * Support repetition scheme (option-2) due to the following   + Repetition schemes are compatible with selection diversity based low complexity receivers that can provide performance within a dB of soft-combining receivers especially in the presence of blockage   + Repetition schemes can support AL16+AL16 (plus inter-slot repetition) providing better performance than AL16 joint-coding scheme even with selection diversity reception * Support both intra-slot and inter-slot mTRP PDCCH repetition that allows joint scheduling of PDCCH across multiple slots at the gNB to reduce blocking probability. * Support dynamic switching between sTRP and mTRP PDCCH transmission to reduce PDCCH blocking probability * Support TDM/FDM and combinations thereof for transmitted PDCCH repetitions from multiple TRPs * Support Alt-3 * Specify linkage of PDCCH candidates between TRP-1 and TRP-2 |
| Xiaomi | * Alt 1 and Alt 3 are more preferred than Alt 2 * Alt 1-1 and Alt 1-3 are more preferred than Alt 1-2 * For Alt 1-3/2/3, Case 1 is more preferred. For Alt 1-2, both Case 1 and Case 2 should be supported * To discuss TCI states configured per SS set if Alt 1-3 is supported * To support two FDM PDCCH candidate sets for two SS set respectively in Alt 1-3 * Option 1 and Option 2 should be considered with higher priority than Option 3 |
| Spreadtrum Communications | * To enable PDCCH transmission(s) with two TCI states, at least one of the following can be further studied:   + Alt 1-1 for one PDCCH candidate case   + Alt3 for two or more PDCCH candidate case * For multi-TRP operation, support the following design in frequency domain resource allocation for PDCCH enhancement   + when precoderGranularity is configured with sameAsREG-bundle, even CCEs/REG bundles within the allocated frequency resource of the Coreset are associated with TCI state 1 and odd CCEs/REG bundles are assigned to TCI state 2.   + when precoderGranularity is configured with allContiguousRBs, first ⌈CCEs/2⌉ /⌈REG bundles/2⌉are associated with TCI state 1 and the remaining ⌊CCEs/2⌋ /⌊REG bundles/2⌋ are assigned to TCI state 2 * For two (or more) PDCCH repetition across multi-TRP, Case 1 can be prioritized for further study * For multi-TRP operation in FDM manner, for the linkage between two sets of PDCCH candidates, at least consider one of the following:   + Method-1: The linkage between PDCCH candidates across multi-TRP can be designed by a pre-defined rule.   + Method-2: The linkage between PDCCH candidates across multi-TRP can be indicated via high layer signalling, e.g. RRC, MAC CE * For multi-TRP PDCCH enhancement, both intra-slot and inter-slot TDM based scheme can be considered for further study |
| Convida Wireless | * Support Alt 1-1 for FDM * Support Alt 3 for TDM   + Support Case 1: PDCCH candidates with the same candidate index are linked |
| NTT DOCOMO, INC | * For Alts:   + Alt. 1-1-b, i.e. one PDCCH candidate is associated with both TCI states for the CORESET, and each RE of the candidate is associated with both TCI states, should be supported for SFN scheme.   + Alt. 1-1-a, i.e. one PDCCH candidate is associated with both TCI states for the CORESET, and different symbols/REs/REGs of the candidate are associated with different TCI states, respectively, can be further studied for no repetition scheme.   + Down select from Alt. 1-3 and Alt. 3 for TDM/FDM repetition/multi-chance scheme.   + Do not support Alt. 1-2 and Alt. 2. * At least support option2 * At least support Case 1 |
| Ericsson | * For single PDCCH approach, further study is needed on resource partitions between two TRPs and their impact on PDCCH performance * Treat intra-slot PDCCH repetition with higher priority than inter-slot repetition * Rather similar spec changes required for Alt.2 and Alt.3. Additional constraints are needed for linked SS sets in Alt.3 * Significant design efforts may be required on REG to TCI state mapping for Alt.1 * TDM should be supported with higher priority in FR2. Both TDM and FDM are supported in FR1 * To support PDCCH repetition within a CORESET associated with two TCI states, changes are needed on PDCCH resource allocation for TDM operation * The benefit of Alt.1-3 with PDCCH repetition in two SS sets associated with a same CORESET activated with two TCI states is unclear * Explicit linkage is required between PDCCH candidates scheduling a same PDSCH/PUSCH/CSI-RS/SRS |
| Qualcomm Incorporated | * Do not consider Option 3 (multi-chance) further * Support Option 1 (no repetition) * The following combinations are valid:   + Combination 1: Alt 1-1 + Option 1   + Combination 2: Other Alts + Option 2 + Case 1   + Combination 3: Other Alts + Option 3 + Case 1   + Combination 4: Other Alts + Option 3 + Case 2 * Specification impact:   + Combination 1 (Alt 1-1 + Option 1) has considerably smaller specification impact compared to other combinations.   + Combination 2 (Other Alts + Option 3 + Case 1) and Combination 3 (Other Alts + Option 3 + Case 1) have significant specification impact. Compared to Combination 2, Combination 3 has slightly smaller specification impact.   + For Combination 2 and 3, specification impact is slightly smaller when Alt 3 is used compared to Alt 1-2, 1-3, and 2.   + Certain issues are not easily solvable for Combination 4 (Other Alts + Option 3 + Case 2) resulting in major scheduling limitations and/or mismatch between UE and gNB * Support Combination 1 (Alt 1-1 + Option 1).   + For FDM scheme in Alt 1-1, study how to associate each REG bundle with a TCI state, including first/second half or even/odd REG bundle splitting rules   + For CCE-to-REG mapping in FDM scheme in Alt 1-1, the REG bundles associated with different TCI states are separately interleaved using the Rel. 15 interleaving formula, and each CCE j is mapped to REG bundles from the first set or REG bundles from the second set   + For TDM scheme in Alt 1-1, precoding granularity is defined within the symbols with the same TCI state for both cases of “precoderGranularity=allContiguousRBs” and “precoderGranularity=sameAsREG-bundle” |

# **Reference**

[1] R1-2007540, Multi-TRP/panel for non-PDSCH FUTUREWEI

[2] R1-2007587 Enhancements on multi-TRP for reliability and robustness in Rel-17 Huawei, HiSilicon

[3] R1-2007627 Reliability Enhancements for PDCCH, PUCCH, and PUSCH InterDigital, Inc.

[4] R1-2007645 Further discussion on enhancement of MTRP operation vivo

[5] R1-2007764 Multi-TRP enhancements for PDCCH, PUCCH and PUSCH ZTE

[6] R1-2007783 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Fujitsu

[7] R1-2007793 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH TCL Communication Ltd.

[8] R1-2007825 Discussion on enhancements on multi-TRP/panel for PDCCH, PUCCH and PUSCH CATT

[9] R1-2008001 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH CMCC

[10] R1-2008149 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Samsung

[11] R1-2008218 Enhancements on Multi-TRP based enhancement for PDCCH, PUCCH and PUSCH OPPO

[12] R1-2008347 Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH Sony

[13] R1-2008439 Views on Rel-17 multi-TRP reliability enhancement Apple

[14] R1-2008574 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH LG Electronics

[15] R1-2008898 On multi-TRP enhancements for PDCCH and PUSCH Fraunhofer IIS, Fraunhofer HHI

[16] R1-2008904 Enhancements for Multi-TRP URLLC schemes Nokia, Nokia Shanghai Bell

[17] R1-2008911 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Lenovo, Motorola Mobility

[18] R1-2008944 Discussion on multi-TRP for PDCCH, PUCCH and PUSCH NEC

[19] R1-2008958 Enhancements on Multi-TRP for PDCCH, PUSCH and PUCCH MediaTek Inc.

[20] R1-2008978 Multi-TRP enhancements for PDCCH, PUCCH and PUSCH Intel Corporation

[21] R1-2009028 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Xiaomi

[22] R1-2009054 Discussion on enhancements on multi-TRP for uplink channels Asia Pacific Telecom co. Ltd

[23] R1-2009130 Enhancements on multi-TRP for PUSCH Sharp

[24] R1-2009142 Discussion on enhancements on Multi-TRP for PDCCHPUCCH and PUSCH Spreadtrum Communications

[25] R1-2009159 Multi-TRP Enhancements for PDCCH, PUCCH and PUSCH Convida Wireless

[26] R1-2009175 Discussion on MTRP for reliability NTT DOCOMO, INC.

[27] R1-2009223 On PDCCH, PUCCH and PUSCH enhancements with multiple TRPs Ericsson

[28] R1-2009251 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Qualcomm Incorporated

# **Appendix: Previous Agreements**

**Agreement**

The following is agreed for evaluation of PDCCH

* According to the evaluation scenario (e.g., at FR1 in urban macro / at FR1 in indoor hotspot / at FR2 in indoor hotspot), one of three Tables (Table A.3-1 ~ A.3-3) of 38.824 can be a baseline of EVM for Rel-17 FeMIMO item 2a.
  + System bandwidth other than those mentioned in the Tables can be considered and reported by the companies.
* In addition, the following table is used for EVM for Rel-17 FeMIMO item 2a (Common assumptions for PDCCH/PUCCH/PUSCH)

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| The number of TRPs | 2 |
| Channel model | TDL for FR1 (CDL for FR1 can be optionally used)  CDL for FR2 (TDL for FR2 can be optionally used) |
| Path-loss modeling | {0,3,6} dB gap between TRPs |
| Blockage | Blockage model from Rel-16 (x dB power offset with probability p): Companies to report x and p, and other assumptions, if any. |
| Target BLER | [10^-3, 10^-4, 10^-5]: BLER values shown in plots should be based on enough number of samples, e.g., ~100/BLER samples |

* The following table is used for detailed assumptions for PDCCH

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Baseline schemes | Option 1: Rel-15 PDCCH  Option 2: Spec transparent SFN  For FR1: Both options 1 and 2 can be considered  For FR2: Option 1. |
| AL | 8 as baseline. Companies are encouraged to simulate other AL’s additionally for different code rate regimes. |
| # of RBs/symbols | 1 or 2 symbols. Companies to report # of RBs. |
| DCI payload | 40+24(CRC)=64 as baseline. Other payload values are not precluded. |
| CCE-to-REG mapping | Both Interleaved and non-interleaved can be considered. Companies to report the assumptions including interleaverSize in the case of interleaved. |
| REG bundling size | 6 and 2 as baseline. |
| Precoding assumptions | Precoding cycling, precoder granularity=REG bundle as baseline.  Closed-loop precoding can be used optionally |
| Schemes | Details of the schemes used (including TDM,FDM, etc.) to be reported by companies. |
| Receiver assumption | Up to companies to report |

**Agreement**

To enable a PDCCH transmission with two TCI states, study pros and cons of the following alternatives:

* Alt 1: One CORESET with two active TCI states
* Alt 2: One SS set associated with two different CORESETs
* Alt 3: Two SS sets associated with corresponding CORESETs
* At least the following aspects can be considered: multiplexing schemes (TDM / FDM/ SFN / combined schemes), BD/CCE limits, overbooking, CCE-REG mapping, PDCCH candidate CCEs (i.e. hashing function), CORESET / SS set configurations, and other procedural impacts.

**Agreement**

For non-SFN based mTRP PDCCH reliability enhancements, study the following options:

* Option 1 (no repetition): One encoding / rate matching for a PDCCH with two TCI states
* Option 2 (repetition): Encoding / rate matching is based on one repetition, and the same coded bits are repeated for the other repetition. Each repetition has the same number of CCEs and coded bits, and corresponds to the same DCI payload.
  + Study both intra-slot repetition and inter-slot repetition
* Option 3 (multi-chance): Separate DCIs that schedule the same PDSCH /PUSCH /RS/TB/etc. or result in the same outcome.
  + Study both cases of DCIs in the same slot and DCIs in different slots

Note 1: Companies are encouraged to evaluate the different options based on agreed LLS assumptions for possible down-selection in RAN1#103-e.

Note 2: The actual encoding / rate matching chain for PDCCH polar coding (i.e. 38.212 Sections 5.3.1 / 5.4.1 / 7.3.3 / 7.3.4) is not changed in the options above.

**Agreement**

For mTRP PDCCH reliability enhancements, study the following multiplexing schemes

* TDM : Two sets of symbols of the transmitted PDCCH / two non-overlapping (in time) transmitted PDCCH repetitions / non-overlapping (in time) multi-chance transmitted PDCCH are associated with different TCI states
  + Aspects and specification impacts related to intra-slot vs inter-slot to be discussed
* FDM : Two sets of REG bundles / CCEs of the transmitted PDCCH / two non-overlapping (in frequency) transmitted PDCCH repetitions / non-overlapping (in frequency) multi-chance transmitted PDCCH are associated with different TCI states
* SFN : PDCCH DMRS is associated with two TCI states in all REGs/CCEs of the PDCCH
  + Note: There is dependency between this scheme and AI 2d (HST-SFN )
* Note: Combinations of the schemes are not precluded, and they can be discussed at a later stage.

**Agreement**

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
* 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
* Note 1: A set of PDCCH candidates contain a single or multiple PDCCH candidates, and a PDCCH candidate in a set corresponds to a repetition or chance
* Note 2: How one or more PDCCH candidates are counted for monitoring (for BD limit) is FFS
  + The note is applicable also to other alternatives

**Agreement**

For Alt 1-2/1-3/2/3, study the following

* Case 1: Two (or more) PDCCH candidates are explicitly linked together (UE knows the linking before decoding)
  + FFS: How the explicit linkage is derived/determined by the UE
* Case 2: Two (or more) PDCCH candidates are not explicitly linked together (UE does not know the linking before decoding)
  + FFS: How the UE knows the linkage after decoding