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

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

**Agenda item:** 8.1.2.1

**Source:** Moderator (Qualcomm)

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

## **PDSCH mapping Type B**

Regarding the open issues on the following agreement, the views are summarized as below:

**Agreement**

If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition

* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with *ReferenceofSLIV-ForDCIFormat1\_2*, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), a reference candidate is used. Select one among the following:
	+ Alt1: The candidate that starts later in time
	+ Alt3: The candidate that starts earlier in time
* FFS: How to define *d1,1* $d\_{1,1}$for PDSCH processing time in this case
* **Alt1 (18): ZTE, Lenovo/MotM, vivo, Spreadtrum, CATT, Fujitsu, OPPO, CMCC, Qualcomm, Apple, LG, Convida, Nokia/NSB, InterDigital, MediaTek, Intel**
* **Alt3 (6): Huawei/HiSilicon, vivo, Samsung, NEC, Ericsson**

Given the majority view, Alt1 is suggested below. From the contributions, it is clear that Alt1 has smaller specification impact and is more consistent with Rel. 15 principle wrt PDSCH processing time.

On *d1,1* determination, the views are not converged yet as summarized below:

* Corresponding to the candidate that starts later in time: Fujitsu
* Corresponding to the maximum among the two candidates: Lenovo/MotM, OPPO, Qualcomm
* Consider number of overlapping symbols of both candidates: Spreadtrum
* Double count one symbol if it belong to both candidates and the PDSCH: Apple
* Depends on BD count and overlapping pattern: vivo
* PDSCH symbols between the earliest and latest symbols of the PDCCH candidates in time are considered overlapping with the PDCCH: Ericsson

Based on the above, more discussions seem to be needed. In existing specification (38.214 Section 5.3), *d1,1* not only depends on the number of overlapping symbols between PDSCH and PDCCH, but also it depends on PDSCH length, processing capability 1 versus 2, and CORESET length (for processing capability 2 and L=2).

For the sake of discussions, the following examples can be used to compare different options on *d1,1*. Given the majority view of Alt1, I suggest to only focus on the case that the earliest PDSCH starting time is the first symbol of the candidate that starts later. Otherwise, the principle/method of *d1,1* calculation itself requires more fundamental discussions. As an example, *d1,1* is always 0 in current spec if the PDSCH length is 7 symbols or larger, which does not need to be changed with Alt1, and hence in the following examples, such cases are not considered. For each example below, processing capability 1 and 2 can also be considered separately. Please feel free to add other examples in the comment section if needed.



***FL Proposal 1: Among the two Alts in RAN1 #104b-e agreement on PDSCH mapping Type B, support Alt1 (The candidate that starts later in time).***

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

* ***Option 1: By considering the PDCCH candidate that starts later in time***
* ***Option 2: By considering the PDCCH candidate that results in larger d1,1 value***
* ***Option 3: By considering the number of overlapping symbols from both PDCCH candidates.***
	+ ***FL note: The intention of this option may be similar to Option 2, but it may not completely characterize the value in case of 3-symbol CORESET with L=2 for processing capability 2.***
* ***Option 4: By double-counting each PDSCH symbol that overlaps with both PDCCH candidates.***
	+ ***FL note: This option may also require more accurate description in case of 3-symbol CORESET with L=2 for processing capability 2.***
* ***Option 5: It depends on BD count and whether soft-combining is performed***
	+ ***FL note: This option may be a combination of other options (e.g. Option 1-3 for 2BDs and Option 4 for 3BDs), but discussions is required whether soft combining should impact the processing time. If yes, other timelines (PUSCH processing, PDSCH processing for mapping Type A, etc.) may need to be also considered.***

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support the proposal and support option2. |
| MediaTek | Support the proposal and prefer option 2 |
| Apple | Support option 4. We have some concerns for option 1/2/3. Currently UE needs to decode 2 PDCCHs, so if we only consider the overlapping status for one PDCCH candidate, it would increase the UE complexity. Option 5 can be additionally considered on top of option 4, but we agree that this is a more general issue. |
| QC | Support the proposal, and support option2 for d1,1. Option 3 can also work for d1,1 but requires some additional conditions to address all cases. We think Option 2 is simpler. |
| Lenovo/MotM | Support the proposal. For determining *d1,1*, We prefer to option 2 because of simplicity and good compatibility to current specification.  |
| LG | In case of 2 BD without soft combining, we support option 2. On the other hand, Discussion on Option 5 have an impact on other options so we would like to first discuss it. Alternatively, we can discuss d11 for the case without soft combining and discuss option 5, separately. |
| Fujitsu | Support the proposal. For *d*1,1, fine with option 1 and option 3 (the solution provided by Ericsson works in case of 3-symbol CORESET with L=2 for processing capability 2.) |
| OPPO | Support FL proposal and prefer option 2. We can also accept Option 4 which relaxes the processing time for UE compared to Option 2.  |
| Xiaomi | Support the proposal and prefer Option 2 |
| Samsung | Support Alt3 (The candidate that starts earlier in time) based on the reasons which we mentioned in our tdoc. Regarding d1,1, we support Option 2 as first, and also fine for Option 4 or 5 to relax the PDSCH processing time. |
| Spreadtrum | Support the proposal. Given that UE should decode 2 PDCCHs w/ or w/o soft combing, there are additional UE complexity than 1 PDCCH decoding. Thus, we think the PDSCH processing time requirement could be relaxed for PDCCH repetition. Either of option 3 and option 4 is fine to us. |
| InterDigital | Support the FL proposal and option 2.  |
| vivo | Based on the proposal draft, if intra-slot based PDSCH repetition and PDCCH repetition are located in same slot configured for URLLC, the scheduling pattern in left figure is only supported in which UE receiver should change 4 beam switching times, while the scheduling pattern in right figure is precluded in which only 2 beam switching times are needed. When UE report capability of beam switchingtimes value (*maxNumberRxTxBeamSwitchDL=****n4****),* there is not any chance to receive other DL signals or transmit UL signals with different beams, which restricts the flexible scheduling pattern in gNB. Furthermore, two PDCCH candidates have to gather in first symbols in left figure, the mutual interference of PDCCH between inter UEs or inter cells in network would increase, and the probability of collision with important CSS would increase which is usually allocated in first symbols too, in general, UE receives CSS with high priority and may drop the PDCCH repetition due to overbooking, it is not good scheme for URLLC.Now that, most companies like option1, the scheduling pattern in right figure can be supported based on option1, the first symbol of PDSCH ahead of the first symbol of PDCCH candidate that starts later in time can be achieved by introducing negative SLIV value.  Regarding processing time about *d1,1*, the overlapping symbols between scheduling PDCCH and PDSCH affects the determination of *d1,1* and our views is presented as follows: In Rel.15, the processing time is subject to the symbol position in time and overlapping pattern, which does not concern how many PDCCH candidates in same time. UE monitor successively these PDCCH candidates in same time and should ensure *d1,1* is still valid in the last monitored PDCCH candidate. In Rel.17, PDCCH repetition is supported, the second PDCCH repetition candidate can be seen as a normal candidate and the third BD for soft bits combining can be seen as a virtual PDCCH candidate. Since same UE capability of BD/CCD is not changed in R17, in other words, the processing time in chipset for every PDCCH candidate do not change, double-counting rule in option 4 and depending on BD count in option5 makes no sense and both options should be precluded. In 38.214, the understanding for *the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH* should be clarified in case of PDCCH repetition. The processing time depends on the actual overlapping symbols of PDSCH no matter the PDCCH repetition, option2 is preferable. The number for three examples from FL is listed in the table.

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|  | **Clafication on:****the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH** |
| Example 1 | 3 |
| Example 2 | 2 |
| Example 3 | 2 |

We suggest revising FL proposal:***FL Proposal 1: Among the two Alts in RAN1 #104b-e agreement on PDSCH mapping Type B, support Alt1 (The candidate that starts later in time).*** ***• introduce negative value for SLIV to support the first symbol of PDSCH ahead of the first symbol of PDCCH candidate that starts later in time.***  ***FFS: which negative values can be supported.******For PDSCH processing time in this case, d1,1 is determined, support option2.******~~• Option 1: By considering the PDCCH candidate that starts later in time~~*** ***• Option 2: By considering the PDCCH candidate that results in larger d1,1 value******~~• Option 3: By considering the number of overlapping symbols from both PDCCH candidates.~~******~~o FL note: The intention of this option may be similar to Option 2, but it may not completely characterize the value in case of 3-symbol CORESET with L=2 for processing capability 2.~~******~~• Option 4: By double-counting each PDSCH symbol that overlaps with both PDCCH candidates.~~******~~o FL note: This option may also require more accurate description in case of 3-symbol CORESET with L=2 for processing capability 2.~~******~~• Option 5: It depends on BD count and whether soft-combining is performed~~******~~o FL note: This option may be a combination of other options (e.g. Option 1-3 for 2BDs and Option 4 for 3BDs), but discussions is required whether soft combining should impact the processing time. If yes, other timelines (PUSCH processing, PDSCH processing for mapping Type A, etc.) may need to be also considered.~~*** |
| ZTE | Support the FL proposal and option 2 for less spec effort.  |

## **The case that one of the linked candidates is dropped**

Company views on the two options from the following agreement is summarized below:

**Agreement**

For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), select one option from Options 1 and 2 in RAN1#105-e:

* Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)
* Option 2: Even the candidate that is not dropped is not monitored (Both linked candidates are dropped if at least one of them is dropped)
* FFS: Which of the following Rel. 15/16 rules are applicable for this purpose:
	+ Case 1: Overlap with SSB
	+ Case 2: Overlap with rate matching resources: RateMatchPattern, lte-CRS-ToMatchAround, or LTE-CRS-PatternList-r16, availableRB-SetPerCell-r16
	+ Case 3: Due to TDD DL/UL related conflicts: Overlap with semi-static / dynamic UL symbols or overlap with PRACH
	+ Case 4: QCL-TypeD prioritization rule among CORESETs result in one of the linked candidates not being monitored
	+ Case 5: Overbooking results in one of the linked candidates not being monitored
	+ Case 6: Overlap with reserved PRB(s) and OFDM symbol(s) indicated by DCI format 2\_1 where UE may assume no transmission intended for the UE
	+ Other cases are not precluded
* FFS: Whether there is an impact to BD count
* **Option 1 (16): Huawei/HiSilicon (other than Case 5), ZTE, vivo, Spreadtrum, Samsung, NEC, OPPO, CMCC, Qualcomm (other than Case 6), Xiaomi, Convida, Nokia/NSB, Ericsson, MediaTek**
* **Option 2 (7): Lenovo/MotM, CATT, FUTUREWEI, Fraunhofer, Apple, Intel**

Given the majority view, Option 1 is suggested below. Since overbooking is discussed separately as some companies may prefer it that way, Case 5 is removed. Also, discussions may be required for Case 6 as mentioned by one company. One question is asked below on Case 6.

Regarding impact to BD counting, views are:

* Yes, BD count is impacted (count 1 BD): ~~OPPO,~~ LG, Ericsson
* No, BD count is not impacted: vivo, Qualcomm, MediaTek, OPPO

As a first step, it may be helpful to align the understanding on Rel. 15 behaviour before we discuss the case of PDCCH repetition wrt impact on BD count. One question is asked below for this.

***FL Proposal 2: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped)***

* ***Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)***
* ***At least the following Rel. 15/16 rules are applicable for this purpose:***
	+ ***Case 1: Overlap with SSB***
	+ ***Case 2: Overlap with rate matching resources: RateMatchPattern, lte-CRS-ToMatchAround, or LTE-CRS-PatternList-r16, availableRB-SetPerCell-r16***
	+ ***Case 3: Due to TDD DL/UL related conflicts: Overlap with semi-static / dynamic UL symbols or overlap with PRACH***
	+ ***Case 4: QCL-TypeD prioritization rule among CORESETs result in one of the linked candidates not being monitored***
	+ ***Case 6: Overlap with reserved PRB(s) and OFDM symbol(s) indicated by DCI format 2\_1 where UE may assume no transmission intended for the UE***
	+ ***Other cases are not precluded***

***Question 1: Please share your view on Case 6 above, and also Rel. 15 behaviour (whether DCI format 2\_1 results in dropping a PDCCH candidate) given that DCI format 2\_1 is received after PDCCH.***

***Question 2: If some candidates are dropped in a certain slot due to Cases 1-4 (or 6), what is the Rel. 15 behaviour in terms of BD count (whether dropping means they are not counted toward the BD limit)?***

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| Company | Comments |
| NTT Docomo | Support the proposal.For question1: our understanding on Rel-15 behavior is DCI format 2\_1 will result in dropping a PDCCH candidate.For question2: our understanding on Rel-15 behavior is dropping does not mean they are not counted toward the BD limit. So, our view regarding impact to BD counting is BD counting is not impacted. |
| MediaTek | Support the proposal.Q1: We think DCI format 2\_1 results in dropping a PDCCH candidate.Q2: BD count is not impacted. |
| Apple | We do not support the proposal. It is unclear whether option 1 would require BD recalculation. BD recalculation would increase UE complexity. |
| QC | Support the proposal except for Case 6.For Q1: We think DCI format 2\_1 is for UE to set some LLR to 0 to help the decoding if the UE has not already processed PDSCH/PDCCH. Just because some CCEs are indicated by DCI format 2\_1 one slot later, it does not mean that UE drops a PDCCH that has already been processed/decoded.For Q2: We also think dropping (cases 1-4 and 6) does not impact the BD counting in Rel. 15. The only place that a candidate is not counted toward the BD limit is when all params are the same, which is a different issue (issue of proposal 3) |
| Lenovo/MotM | We still have concern on PDCCH reliability for option 1. For example, the PDCCH reliability can not be guaranteed for the case that the candidate with good channel quality is dropped and the linked candidate with bad channel quality is monitored. For question 1, case 6 may be considered since it has impact on blind decoding for the second candidate when soft combining is used for later candidates although it may not have impact on blind behavior for the first candidate on account of indicating information for previous slot.For question 2, if option 1 is agreed, we think BD count is impacted and 1 BD is counted to align with decoding algorithm in case of dropping one candidate. |
| LG | It seems better to have a common understanding for Q1 and Q2 before selecting one of options. |
| Fraunhofer IIS/HHI | We agree with Lenovo’s views on option 1. However, to answer Q2, a BD count of 1 is applicable for option 1 corresponding to the candidate that is not dropped. |
| Fujitsu | Support the proposal.For question 1, we don’t think DCI format 2\_1 results in dropping a PDCCH candidate.For question 2, we share similar views with Docomo and QC. The PDCCH candidate dropping does not impact BD count.  |
| OPPO | Support the proposalFor Q1: We think PDCCH candidate will be dropped in the case that DCI 2\_1 notifies no transmission on the resource that overlaps with the resource of such PDCCH candidateFor Q2: Dropping does not impact BD count in Rel-15. Following the same principle, we tend to agree that BD count is not impacted by Proposal 2.  |
| Xiaomi | Support FL Proposal 2.For Q1: we think DCI format 2\_1 will not result in dropping a PDCCH candidate overlapped with the reserved resource. Since the DCI format 2\_1 is used to indicate the reserved symbols prior to itself, it means the PDCCH candidate overlapped with the reserved symbols has been decoded. For Q2: we think in Rel-15, dropping doesn’t mean they are not counted. |
| Samsung | Support the proposal. For Q1: We think PDCCH candidates which are overlapped with reserved PRB(s) and OFDM symbol(s) indicated by DCI format 2-1 are dropped.For Q2: We have same understanding with NTT Docomo and Qualcomm that there is no impact on BD counting regardless of dropping. Based on the same manner, BD should not be impacted for the case considered in this proposal. |
| Spreadtrum | Support the proposal.For Q1: In our understanding, DCI format 2\_1 would not result in dropping a PDCCH candidate.For Q2: In our understanding, in Rel-15 PDCCH candidates dropping due to the above case does not influence BD counting. |
| InterDigital | Support FL’s proposal. Q2: we agree that BD count is not impacted when a PDCCH candidate is dropped.  |
| vivo | Support the proposal in general.**For question1:** In R15, PDCCH is dropped by UE since the performance of PDCCH cannot be guaranteed without retransmission mechanism which PDSCH transmission adopts.In R17, PDCCH repetition is supported, there is no need to drop PDCCH due to preemption indication, UE can perform soft bits combining analogous to CC (Chase Combine) of PDSCH retransmission and value of soft bits in preemption REs is zero. Therefore, **case6 in FL proposal not relevant.****For question2:** Because overbooking count is usually based on RRC configuration rather than dynamic calculation per slot, so this legacy definition (BD count is not impacted) should be reused for PDCCH repetition in Rel17. |
| ZTE | We support the proposal in principle. However, Case 6 should be put FFS before we get consensus. **For question 1:** in our understanding for Rel-15, DCI format 2\_1 is only used for PDSCH interruption based on Rel-15 discussion even though the current spec is unclear. So we think PDCCH should not be dropped. Further, there is no retransmission, no RV combining, it is unnecessary to drop PDCCH especially for PDCCH repetition with individual detection.**For question 2:** We think the number of BD should be 1 for non-dropped PDCCH candidate as there is no need to do soft combining, especially when the PDCCH drop is caused by some semi-static resources with higher priority. For example, for Case 1 with SSB overlapping, it is easy for UE to know whether one of PDCCH repetition is dropped or not before real PDCCH transmission. Then, UE can assume the number of BD for non-dropped PDCCH candidate as 1. There is no extra UE complexity. In such case, system efficiency is improved as more PDCCH may be detected. |

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

On the three options from the following agreement, views are summarized below:

**Agreement**

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

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

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

* Distinguished by different RNTIs defined for the linked candidate versus the individual candidate
* Distinguished by aggregation level restrictions that can be expected by the UE in the case of overlap
* Option 1 (13): Huawei/HiSilicon, ZTE, vivo, Fujitsu, NEC, CMCC, Qualcomm, Apple, DOCOMO, Nokia/NSB, TCL
* Option 2 (8): Lenovo/MotM, Spreadtrum, Samsung, OPPO, LG, InterDigital, Intel
* Option 3 (8): CATT, FUTUREWEI, Fraunhofer, LG, Xiaomi, Ericsson, InterDigital, Intel

Given that Option 1 has slight majority view, it is proposed below. Furthermore, the impact to the non-overlapped linked candidate in options 2 and 3 requires further discussions. Also, one company proposed to not change the BD counting for this issue. However, it should be noted that this issue is different than issue of Section 2.2, and it is already agreed that one candidate is not counted in this case from a previous agreement. Also, one company proposed to have a max limit on such overlaps, but more discussions may be needed.

***FL Proposal 3: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI:***

* ***Option 1: The individual candidate is not counted for monitoring***
	+ ***Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).***

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support the proposal if individual candidate will have lower priority than linked PDCCH candidate in overbooking. Prefer option 3 if Alt.2 in proposal2.5 is supported for overbooking.We would like to share our views that this issue is related to issue 2.5 overbooking.In our understanding, option1 is reasonable only if individual candidate will have lower priority than linked PDCCH candidate in overbooking. The reason is if individual PDCCH candidate has lower priority than linked PDCCH candidate in overbooking, when counting toward BD limit, the linked PDCCH candidate will be counted and allocated before the individual PDCCH candidate. Then it is reasonable that the individual PDCCH candidate is not counted, because it is already counted when counting to the linked PDCCH candidate overlapped with it.However, if individual candidate will have higher priority than linked PDCCH candidate in overbooking, it is not reasonable because if the individual PDCCH candidate is not counted, and if when counting to the linked PDCCH candidate, the linked PDCCH candidate cannot be allocated due to overbooking, this PDCCH candidate cannot be monitored by UE. |
| MediaTek | As we already mentioned in our Tdoc, the meaning of “is not counted for monitoring” is that the UE still needs to monitor two overlapped candidates but it is just counted once for BD because it is a byproduct of the same decoding. In this case, the UE still parses both overlapped candidates following the associated search space sets.However, in Rel-17, when one of linked candidates and one individual candidate are overlapped and they are associated with the same DCI size, scrambling, and CORESET, one of overlapped candidates should not be monitored (or should be dropped) because it is not a byproduct of the same decoding (Decoding for individual candidate is different from decoding for linked candidate.). Please refer to our Tdoc for the issue. Therefore, the wording of “is not counted for monitoring” should be changed to “is not monitored” like FL Proposal 2. Thus, we have the following proposal. ***FL Proposal 3: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI:**** ***Option 1: The individual candidate is not monitored ~~counted for monitoring~~***
	+ ***Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).***
 |
| Apple | Support the proposal |
| QC | Support the proposal if we the following is added:* **The max limit on number of such overlaps is up to UE capability.**
	+ **FFS: The details of UE capability**

The reason for the above is explained below: “not counting a candidate for monitoring” is not completely free in terms of UE complexity (even though UE does not perform additional blind decoding). This is because the UE is still required to identify “duplicate candidates”, which can change in different monitoring occasions depending on SS set configurations. To be more specific, there is currently no limit on the maximum number of “duplicate candidates”, which needs to be checked before performing BD on a per-slot basis. This means that even though the UE performs up to 44 BDs per slot for 15 KHz SCS, it still may have to deal with 44\*10=440 candidates in theory if the network configurations result in 10 SS sets that are overlapping in a slot, and identify which ones do not require BD operation. This is a non-trivial amount of processing at the UE side especially in the presence of PDCCH repetition. Hence, we think there should be a limit on how many of these overlapping candidates the UE can deal with, which can be up to UE capability.  |
| Lenovo/MotM | Slightly prefer option 2 since it reuses priority rule defined in Rel.15/16 and has smaller standard impact. Furthermore, Option 2 and 3 can provide flexibility to protect individual candidate with high priority.  |
| LG | Option 2 and 3 are almost same but how to apply SS set ID for priority based selection is different. We can merge these two options and leave the difference FFS. In addition, Option 2 and 3 provides more scheduling flexibility since individual candidate can have high priority. For example, if individual candidate requires much lower latency than linked candidate whose main usecase is for reliability increase, individual candidate should be monitored instead of linked candidate. We revise the proposal as shown below:***Proposal 3: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI:**** Option 2’ (Option 2 and 3 are merged): The candidate in a higher SS set ID is not counted for monitoring
	+ Interpretation of the detected DCI depends on which candidate is not counted (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).
	+ FFS: Impact to the other linked PDCCH candidate
	+ FFS: For SS set ID for the linked PDCCH candidate, whether to use SS set ID of the linked PDCCH candidate or a lower SS set ID of the two linked SS sets.
 |
| Fraunhofer IIS/HHI | Taking the SS set ID of the PDCCH candidate into account is in line with the BD counting of Rel. 15/16 based on SS set priority. In addition, the priority of the linked PDCCH candidate has to be determined which could be based on the lowest SS set ID among the PDCCH candidates. Option 3 is preferred as it satisfies both these criteria. |
| Fujitsu | Support the proposal. |
| OPPO | Do not support the proposal. If individual candidate is not counted for monitoring, then the Rel.15 overbooking rule is disobeyed which means linked PDCCH candidates always have the highest priority to monitor. It will reduce the flexibility of gNB implementation. In contrast, Option 2 is more flexible and can achieve the same purpose of Option 1/Option 3 by proper configuration.This issue is related to Issue#2.5. We prefer to achieve some agreement for Issue#2.5 as a first step and then keep the solution of this issue consistent with that of Issue#2.5.MTK’s comment on the wording “is not counted for monitoring” is a good point. We support to clarify it.  |
| Xiaomi | We share same view as LG that Option 2 and Option 3 provides more scheduling flexibility. We slightly prefer Option 3 that same priority is configured to two linked SS sets. |
| Samsung | Support Option 2 as it has a minimal specification impact and can control the priority based on proper gNB configuration.  |
| InterDigital | Do not support the proposal. We think the unlinked candidate should not always be considered lower priority, and leave it up to the gNB configuration of SS sets to determine the priority.  |
| vivo | Option 1 is a simple and clear scheme. Support FL’s proposal. Besides, we have a question that what the relationship or priority between this issue and issue 2.6 is. For example, when individual PDCCH candidate has higher QCL-typeD priority, it seems there is still a contradiction with option1. we expect to hear more comments for other companies on it.  |
| ZTE | Support FL proposal. @vivo The condition here is that individual PDCCH and one of PDCCH repetition are from the same CORESET which means they have the **same QCL-typeD**. So there is no issue related with 2.6. @QC we prefer to discuss UE capability later.  |

## **Details of number of BDs**

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

**Agreement**

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

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

With respect to the above FFS’s, the following views were expressed in contributions:

* 3 BDs implies soft-combining: Huawei/HiSilicon, ZTE, CATT, FUTUREWEI, Fraunhofer, DOCOMO, Ericsson
* If UE supports 3BDs, gNB can configure 2 BDs: Huawei/HiSilicon, ZTE, vivo, Lenovo/MotM, CATT, Qualcomm, LG, DOCOMO, Ericsson
* For 2 BDs, soft combining can be UE capability / RRC configuration: ZTE, Fraunhofer, InterDigital
* Non-integer number of BDs: Lenovo/MotM

At least the first two bullets above seem to have good support, and they are suggested below. Note that we should try to not go back to the earlier options (Option 1-5, e.g., decoding assumptions, explicit indication of soft combining support) given the agreement above. Otherwise, the discussions in RAN1 #104b-e will be repeated again.

***FL Proposal 4: RRC configuration for counting two linked PDCCH candidates as 3 BDs is supported.***

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

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support  |
| MediaTek | Support |
| Apple | We failed to see the necessity for the proposal. |
| QC | We think the second bullet (soft combining) is not needed since it may not have RAN1 specification impact. RAN4 can decide to consider the performance aspects.  |
| Lenovo/MotM | Support FL’s proposal for RRC configuration for BD number in general. Also, we are open for discussing whether other values for implicitly implying soft combining can be carried by RRC signalling (NOT UE reporting). Moreover, we want to clarify whether 2 BDs can be configured for UE performing soft combining (e.g. 1 BD based on LLR from first candidate and 1 BD based on LLR from combined LLR from first and second candidate).  |
| LG | If we discuss whether soft combining is conducted or not for 2 BDs, how does RAN 4 set the test requirement for 2 BDs?  |
| Fraunhofer IIS/HHI | We prefer that soft-combining capability is known to the gNB as in the case of reported BD count of 2, it may mean that the UE performs either selection decoding or soft-combining. |
| Fujitsu | Support the proposal. |
| OPPO | Support the main sentence and the 1st bullet by the modification: RRC configuration for counting two linked PDCCH candidates as 2 or 3 BDs is supported* The 2nd bullet: As a general principle, UE implementation is not captured in RAN1 spec
* The 3rd bullet: it is up to the RRC signaling design
 |
| Xiaomi | Support the proposal |
| Samsung | Although we think the second bullet is not needed, if the second bullet is really needed, then a conclusion is enough. Also, as mentioned by Lenovo, soft combining can be used from the UE side even with 2 BDs. |
| Spreadtrum | Following the proposal, does it mean that soft combing could not be assumed for 2BDs? |
| InterDigital | Since soft-combining is possible with 2 BDs, then we think soft-combining capability should be reported.  |
| vivo | Support  |
| ZTE | Support in principleFor the second bullet, we think it should be revised as***When 3 BDs are supported and configured, it implies UE performs both soft combining and individual decoding***If companies have concern on the second bullet, we suggest to send an LS to RAN4 to inform RAN1’s understanding and let RAN4 finally check the feasibility.  |

## **Overbooking**

There were various proposals on overbooking for PDCCH repetition, which are summarized below at high-level:

* Alt1: Per individual SS set dropping similar to Rel. 15:
	+ Alt1-1: Count the third BD as a virtual SS set: vivo
	+ Alt1-2: Count the third BD as part of higher SS ID: OPPO, Qualcomm
	+ Alt1-3: Half of the BDs per SS set with individual dropping: Ericsson
* Alt2: Consider the SS set pair together (Keep all or drop all): Huawei/HiSilicon, Lenovo/MotM, DOCOMO
* Alt3: Per linked candidate level / MO’s (instead of per SS set level): Samsung, CATT

One observation is that some of the discussions consider both cases of 2BDs and 3BDs, while other discussions only considered the case of 3BDs for overbooking enhancements. Hence, it would be helpful to also discuss whether both cases require overbooking enhancements or not. The following proposal captures the above options and the two cases. Furthermore, there has been some discussions on inter-span based PDCCH repetition, but we can first focus on Rel. 15 PDCCH monitoring or intra-span case.

***FL Proposal 5: For overbooking in the PCell for USS with two linked SS sets in the same slot/span:***

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

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | We would like to add one more alternative that linked PDCCH candidates have higher priority than individual PDCCH candidates in overbooking under both case1 and case2.* Alt.2a: Consider the SS set pair together (both are kept or both are dropped), where the priority of linked SS sets are higher than individual SS sets, the priority among linked SS sets is based on lower SS set ID among the pair.

Our 1st preference is alt.2a and 2nd preference can be alt.2 so that the monitoring of PDCCH repetition can be guaranteed.And as we commented in section2.3, we think issue 2.3 and 2.5 are related. |
| MediaTek | For case1 and case2, prefer Alt 2  |
| Apple | We suggest a common solution for both cases. Support Alt2 for both cases. |
| QC | For Case 1, we do not see why any Alt other than Alt1 (no change) would be needed.For Case 2, our preference is Alt1-2. |
| Lenovo/MotM | Prefer Alt.2 for both case 1 and case 2 as an unified solution since it reuses overbooking principle defined in Rel.15/16 with enhanced granularity of search space set pair.  |
| LG | For Case 1, Alt 1 since there is no soft combining. For Case 2, we are fine with Alt1-2.  |
| Fujitsu | Support the proposal. Prefer Alt2 for both case 1 and case 2. |
| OPPO | For case 1, support Alt 1.* Alt.2: Even if one candidate is dropped, gNB can still use another candidate to schedule transmission. Thus, it is not efficient for the system to drop the remaining candidate.
* Alt.3: It is not preferable to introduce any new dimension (candidate-level rather than SS-set-level) for overbooking

For case 2, support Alt 1-2.* Alt1-1: no need to introduce new type of SS set
* Alt.1-3: Not reflecting the real implementation
* Alt.2: same comment as for case 1
* Alt.3: same comment as for case 1
 |
| Xiaomi | For case 1, we prefer Alt 1 if no soft combining, else we prefer Alt 2.For case 2, we prefer Alt 2. |
| Spreadtrum | For case 1, Alt 1; |
| InterDigital | For both cases, we prefer Alt 2.  |
| vivo | For case 1 support Alt1. For case 2 support Alt1-1. * Case1: 2 BDs are counted

Comparing with Alt1, there is no doubt that Alt2 increases the PDCCH dropping probability especially many PDCCH repetition candidates are associated with same two linked SS sets, once BD count exceeds the limit, all of linked PDCCH repetitions are dropped.Alt3 is a new rule which can reduce PDCCH dropping probability, but UE should perform new overbooking rule in some slots, legacy overbooking rule in some slots and mixed overbooking rule in other slots. Also the priority of candidate level or MO level should be further studied and need more discussion.For case1, we **prefer Alt1 which has no spec impact.*** Case2: 3 BDs are counted

Just as case1, Alt1 is preferred too for case2. Regarding Alt1-3, 1.5x BD per candidate is counted in each linked SS sets, the final non-integer number may appear per SS set, furthermore, Alt1-3 cannot be applied to inter-span PDCCH repetition, since BD is counted in span level.Regarding Alt1-2, when BD number 3 is assumed, there are still much higher probability that the second search space set is dropped since the last two BD should be counted in second PDCCH candidate. Regarding Alt1-1, which obeys rule of R15 indeed that 1BD is for one candidate. For the special third BD only executing extra polar decoding without CCE count, a virtual SS can be introduced to represent. In the following figure, the first 2BDs count is same as case1, when the third BD exceeds the BD limit, at least SS\_k and SS\_k+1 are reserved and UE still detect two PDCCH repetition candidates for better reliability. **Alt1-1 for case2 is extension of alt1 for case1.**Besides aforementioned views, the order of relationship of two linked SS set IDs should be discussed. For TDM based PDCCH repetition, if the latter PDCCH candidate with higher SS set ID is dropped due to BD limit restriction, the former PDCCH candidate with lower SS set ID is saved, UE can decode PDCCH as early as possible. The following description should also be part of the proposal. **For two linked SS set IDs, PDCCH candidate that starts earlier in time is associated with lower SS set ID, while PDCCH candidate that starts later in time is associated with higher SS set ID.** |
| ZTE | For Case 1, we support Alt.1. For Case 2, we support Alt.1-2. For both cases, Alt 3 needs too much spec effort. Alt 2 will cause resource waste since both two linked SS sets are always dropped even only one of them leads to overbooking.  |

## **Determination of two QCL-TypeD**

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

**Agreement**

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

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

The views are summarized below:

* Alt1: Identify the two QCL-Type D properties based on legacy priority order:
	+ OPPO, LG, Nokia/NSB, Intel, ZTE
* Alt2: Reuse legacy priority rule to identify the first QCL-TypeD properties, and then, identify the second QCL-TypeD according to one of the SS set that is linked with the SS set with the first QCL-TypeD
	+ Huawei/HiSilicon, CMCC, Nokia/NSB, Qualcomm
* Alt3: Assign same priority for two linked search space sets for PDCCH transmission with overlapping monitoring occasions (and linked SS sets in USS have higher priority than individual SS set)
	+ Lenovo/MotM, Apple, DOCOMO, Xiaomi, Ericsson, CATT
* Alt4: Based on group beam pair reported by the UE for simultaneous reception
	+ vivo, Apple
* Alt5: First CORESET is determined among unlinked candidates; second CORESET is determined among linked candidates:
	+ Spreadtrum

Given the above, more discussions seem to be necessary. For example, the following clarifications may be helpful in addition to pros/cons of each Alt.

* In Alt1:
	+ The role of PDCCH repetition configurations (linked SS sets)
* In Alt2:
	+ The case that there are multiple such linked SS sets
	+ The case that there is no such linked SS set (i.e., whether second QCL-TypeD should be still identified, e.g., based on Alt1, or not)
* In Alt3:
	+ The case that the first QCL-TypeD is from CSS, but linked SS sets are all USS with two different QCL-TypeD than the first one.
* In Alt4:
	+ The details of the exact rule including timeline wrt beam report by UE, the case that there are multiple such beam pairs in one or more CCs, and relationship to existing QCL-TypeD prioritization rule, etc.
* In Alt5:
	+ The details of this alternative and motivation

Please share your views / preferences among the Alts above, and feel free to clarify the details for each Alt. A proposal will be drafted based on views and clarifications.

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Our 1st preference is Alt.3 and 2nd preference is alt.2For Alt.3, our understanding is * If the highest priority CSS is with one QCL-typeD, first QCL-typeD is from the CSS, then one solution is UE only monitors with one QCL-D, another solution is to find a second QCL-typeD with alt.2 or alt.1.
* if there is no CSS, and there is linked SS sets, then two QCL-typeD can be found.
* If there is no linked SS set, one solution is UE only monitors with one QCL-typeD, another solution is to find second QCL-typeD with alt.1.

For Alt.2, our understanding is* A highest priority SS set is found based on legacy rule
* If multiple such linked SS sets are found, one solution is the priority is based on the SS set ID, another solution is the priority is based on the lower SS set ID of the pair of linked SS sets
* If no such linked SS set is found, one solution is UE only monitors with one QCL-typeD, another solution is to find second QCL-typeD with alt.1.

Meanwhile, it needs to be noticed that if alt.1 is used, NW need to make proper configuration of SS sets so that the two QCL-typeD determined from Alt.1 can be received simultaneous by UE. |
| MediaTek | Fine with the Alt 2 and Alt 3. Alt 1 didn’t consider the linked SS sets in two CORESETs. |
| Apple | Some details for Alt3/4 are provided as follows:For Alt3, our understanding is the same as Docomo’s.For Alt4, * Timeline: In slot n, the QCL-TypeD collision handling can be based on the latest beam report before slot n-k, where k can be fixed, e.g. 4 slot
* Multiple beam pairs reported: for each beam pair, identify the corresponding SSs and determine the priority for a beam pair based on the maximum priority of the SSs, where legacy priority rule can be used for the SS priority selection.
 |
| QC | We support Alt2. Here are clarifications on Alt2:* The case that there are multiple such linked SS sets
	+ In this case, we should follow Rel. 15 priority based on SS set ID
* The case that there is no such linked SS set (i.e., whether second QCL-TypeD should be still identified, e.g., based on Alt1, or not)
	+ In this case, we should find second QCL with Alt1 (no reason to waste UE capability of simultaneous reception)
 |
| Lenovo/MotM | Prefer Alt.3. For details of Alt.3, we have same understanding as Docomo.  |
| LG | We have a question on Alt 3. According to legacy rule, there are three level of priority rule; SS type (USS/CSS), cell index, and SS set ID. Then, if linked SS sets has higher priority than individual, which level the new priority is considered in? It should not be higher level priority than SS type. Otherwise, USS can have higher priority than CSS.  |
| Fujitsu | Prefer Alt2, we share similar view with Docomo on Alt2. |
| OPPO | We support Alt 1 since Alt.2/3 can be achieved by proper configuration. The examples are as below* Alt.2: If the adjacent numbers are used as the IDs of the linked SS sets, Alt.1 can achieve the same purpose as Alt.2
* Alt.3: If the IDs of liked SS sets are configured to be lower than that of the individual SS set, Alt.1 is the same as Alt.3

For Alt.1, if only one SS set out of the linked SS sets is selected, the UE will only monitor this PDCCH candidate and drop the another linked candidate |
| Xiaomi | We prefer Alt 3.For details of Alt 3, priority rules include SS type, cell index and SS set ID. In Alt 3, CSS set has higher priority than USS set regardless of linked SS set or individual SS set; with the same SS type, SS set with lower ID will have higher priority. And for the two linked SS sets, it assumes that they will have the same priority as the SS set with lower ID. And we should note that if the two linked SS sets are TDM, only one QCL-Type D associated with one of two SS sets will be selected in each PDCCH occasion. For details of Alt 1, it is possible that only one QCL Type D associated with one of two SS sets is selected even two PDCCH candidate are FDM. In this case, the reliability will be degraded.For details of Alt 2, there is a problem if the first QCL-TypeD is associated with an individual SS set or associated with one of two linked SS sets by TDM. For Alt 4, we think the determined two QCL Type D should be received by UE simultaneously.  |
| Samsung | We support Alt3 and Alt2 as 1st and 2nd preference, respectively.BTW, we would like to ask companies when this feature (using two QCL-TypeD properties for multiple overlapping CORESETs) is used, i.e., when the number of monitored QCL-TypeD properties is two. - One solution is that at least linked SS sets are configured for all CCs, which is semi-static way. We guess that one of the motivation of issue 2.6 starts from this (to receive two different QCL-TypeD properties).- Another solution is that the number of monitored QCL-TypeD properties depends on the PDCCH monitoring occasion, which is more dynamic way. For second solution, if a certain overlapping PDCCH monitoring occasions in multiple CORESETs only contains CORESETs which are all associated with individual SS set for all CCs, then the number of monitored QCL-TypeD properties can be 1. |
| Spreadtrum | Some details for Alt.5 provided below:* + - Classify all CORESETs into two sets:

-CORESET Set 1: CORESETs not associated with linked SS(s);-CORESET Set 2: CORESETs associated with linked SS(s);* + - Reuse legacy priority rule to identify the first QCL-TypeD properties from CORESET set 1

and then, identify the second QCL-TypeD according to one of the SS set that is linked with the SS set with the first QCL-TypeD from CORESET set 2 |
| InterDigital | Support Alt1. Similar to OPPO, other alternatives can be achieved by proper configuration of SS set indices.  |
| vivo | * Regarding Alt1, two QCL-Type D properties based on legacy priority order, it seems that Alt1 has nothing to do with PDCCH repetition. However, issue 2.6 is raised due to PDCCH repetition schemes that are introduced in R17, e.g. FDM based or SFN based. we do not think Alt1 is beneficial for PDCCH repetition.
* Regarding Alt2, there are still some problems to be resolved. For example, the first QCL-TypeD is selected from CORESET ID0, but one PDCCH repetition group is associated with CORESET0 and CORESET1, another PDCCH repetition group is associated with CORESET0 and CORESET2. How to confirm the second QCL-TypeD from CORESET1 or CORESET2 should be further discussed.
* Regarding Alt3, it fits into the origin of the issue2.6, the logic of Alt3 is similar as option1 of issue2.2 and option2 of issue2.3. However it still consider the priority of two PDCCH repetition group as the above example in second sub-bullet.

We slightly prefer Alt3.  |
| ZTE | Similar view as OPPO. We support Alt1 to strive for reusing the existing priority rules, also for simplicity. In addition, the same issue is under discussion for MTRP HST. Alt 1 could be the unified solution for HST as well.  |

## **Remaining issues for TCI field no present**

The following was agreed in RAN1 #104b-e:

**Agreement**

If a PDSCH is scheduled by a DCI in PDCCH candidates (the first PDCCH candidate associated with a first CORESET and the second PDCCH candidate associated with a second CORESET) that are linked for repetition,

* **Working assumption**: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.
* If the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable, PDSCH QCL assumption is based on the CORESET with lower ID among the first and second CORESETs
* FFS: Whether additional options are needed (e.g. to enable SDM/FDM/TDM PDSCH schemes w/o TCI field in the DCI)

The two remaining issues are related to the working assumption and the FFS. Views are summarized below:

* Confirm WA: vivo, Qualcomm, Spreadtrum, Ericsson, ASUSTeK, InterDigital, ZTE
* In addition, support using both beams: Huawei/HiSilicon, CATT, Fujitsu, LG, DOCOMO, Convida

There seem to be no company opposing to confirm the working assumption based on the contributions. Also, there is some level of interest for the case of using both beams for PDSCH to enable SDM/FDM/TDM schemes w/o TCI field in the DCI. Hence, the following proposal is suggested.

***FL Proposal 7: If a PDSCH is scheduled by a DCI in PDCCH candidates (the first PDCCH candidate associated with a first CORESET and the second PDCCH candidate associated with a second CORESET) that are linked for repetition:***

* ***Confirm the WA: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.***
* ***In addition to the previous agreement, support the following for the case that at least one TCI codepoint is mapped to two TCI states (and if the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable)***
	+ ***QCL assumption of both CORESETs are used for the scheduled PDSCH.***

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support the proposal except the following part marked as yellow in the second bullet of the proposal. In our understanding, the behavior “QCL assumption of both CORESETs are used for the scheduled PDSCH” can be enabled by RRC parameter. If enabled, the PDSCH scheduled by M-TRP PDCCH repetition is assumed to be M-TRP PDSCH and apply two default beams, otherwise, the PDSCH is assumed to be S-TRP PDSCH and apply one default beam. We would like to understand the motivation of the following part marked as yellow.* In addition to the previous agreement, support the following for the case that at least one TCI codepoint is mapped to two TCI states (and if the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable)
	+ QCL assumption of both CORESETs are used for the scheduled PDSCH.
 |
| MediaTek | Support the proposal |
| Apple | Support to confirm the WA only. The second bullet may have impact on common PDSCH reception. |
| QC | Support the first part of the proposal (confirm the WA). For the second part, we do not think there is enough motivation to change the Rel. 16 mTRP PDSCH behavior in this agenda item. |
| Lenovo/MotM | We share the same concern on “at least one TCI codepoint is mapped to two TCI states” as NTT Docomo. From our understanding, SDM/FDM/TDM schemes is not enabled by at least one TCI codepoint is mapped to two TCI states. Besides, for case when no TCI present for all CORESETs, there may be no MAC-CE activation up to 8 TCI codepoints, and even no “at least one TCI codepoint is mapped to two TCI states”. However, the SDM/FDM/TDM schemes could still be implemented in such case by using the TCI state for both CORESETs. Therefore, we suggest to keep it as the original wording.FL Proposal 7: If a PDSCH is scheduled by a DCI in PDCCH candidates (the first PDCCH candidate associated with a first CORESET and the second PDCCH candidate associated with a second CORESET) that are linked for repetition:* Confirm the WA: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.
* In addition to the previous agreement, support the following for enabling SDM/FDM/TDM schemes, (and if the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable)
	+ QCL assumption of both CORESETs are used for the scheduled PDSCH.
 |
| LG | Support the proposal. |
| Fraunhofer IIS/HHI | Support confirming the WA |
| Fujitsu | Support the proposal in general. We also think that RRC parameter is also a viable way to determine the corresponding PDSCH is m-TRP or s-TRP. |
| OPPO | Support to confirm the WA. Further discussion is needed for the 2nd part |
| Xiaomi | We have same concern as NTT Docomo and Lenovo/MotM. We suggest to add “if a UE is configured with *enableTwoDefaultTCIStates*” ***FL Proposal 7: If a PDSCH is scheduled by a DCI in PDCCH candidates (the first PDCCH candidate associated with a first CORESET and the second PDCCH candidate associated with a second CORESET) that are linked for repetition:**** ***Confirm the WA: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.***
* ***In addition to the previous agreement, support the following for the case that*** if a UE is configured with *enableTwoDefaultTCIStates* ***and at least one TCI codepoint is mapped to two TCI states (and if the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable)***

***QCL assumption of both CORESETs are used for the scheduled PDSCH.*** |
| Samsung | Support the proposal. |
| Spreadtrum | Support to confirm the WA. |
| InterDigital | Support confirming the WA, and agree with Qualcomm regarding the second bullet.  |
| vivo | Do not support the second bullet. If SDM or FDM based PDSCH repetition is configured in FR2, UE must support reception of two different QCL-typeDs simultaneously. If UE cannot receive the two current TCI states of both CORESETs simultaneously, the default beam for PDSCH reception based on second bullet cannot work. We think UE capability of simultaneous reception of different QCL-typeD for PDCCH and for PDSCH is independent. For example, UE reports a capability of only supporting single QCL-typeD of CORESET in same time, NW can configure flexible TCI states for CORESETs, which is not suitable for SDM/FDM based PDSCH reliability schemes.  |
| ZTE | Support to confirm the WAFor the second bullet, we have the similar question as DOCOMO, Lenovo and Xiaomi. The motivation is to use two beams of linked CORESETs to buffer PDSCH, we think it can be used no matter what PDSCH schemes are used. Thus, the condition ‘at least one TCI codepoint is mapped to two TCI states’ is not needed. It is noted that Rel-16 SDM/TDM/FDM cannot be used for PDSCH scheduled by a DCI without TCI field.  |

## **CORESETPoolIndex**

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

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

From moderators perspective, it would be good to close this issue by agreeing to one of the alternatives above given that this topic has been discussed for two or more meetings already.

Please indicate your preference(s) among the Alts above:

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support Alt.2. |
| MediaTek | Support Alt 3. |
| Apple | Support Alt 2/3. |
| QC | Support Alt2. We do not see a use case for Alt1, and specification impacts are too much.Also, we did not see a reason for the restriction of Alt3. |
| Lenovo/MotM | Slightly prefer Alt.2/3 on account of specification effort and typical application scenario. |
| LG | Support Alt 1. In case of Alt 2, in order to configure m-DCI and PDCCH repetition simultaneously, more CORESETs are needed than Alt 1. Specifically, at least 3 CORESETs are needed for Alt 2 but it can be supported with 2 CORESETs in Alt 1. |
| Fraunhofer IIS/HHI | Support Alt. 1.With Alt. 2, when multiple CORESETpoolIndex values are configured, only single TRP based PDCCH repetition would be possible.In the case of Alt. 3, PDCCH repetition would be possible only with sDCI-based MTRP PDSCH. Alt. 1 provides the most flexibility as MTRP PDCCH can co-exist with any type of MTRP PDSCH. |
| Fujitsu | Support Alt.2. |
| OPPO | Support Alt 3. During R16 M-TRP design, it is a common understanding each CORESETPoolIndex corresponds to a different TRP. Alt.1/2 will not be aligned with this common understanding |
| Xiaomi | Support Alt 2 |
| Samsung | Support Alt1. |
| Spreadtrum | Fine with Alt 2 or Alt3 |
| InterDigital | Support Alt 2.  |
| Vivo | Support Alt3.Support Alt2 with some restriction. In Rel.16, if S-DCI based PDSCH repetition is configured, the configuration for different CORESETPoolIndex value is prohibited. We suggest same rule is taken for PDCCH repetition in R17. Regarding Alt2, can be supported in one special case, two PDCCH repetition candidates should be from single TRP. For instance, two linked SS sets are associated with single CORESET ID. |
| ZTE | Support Alt 1. Rel-16 MDCI based MTRP is the most desirable feature for MTRP. If it cannot be used together with Rel-17 PDCCH repetition, the Rel-17 feature may not be deployed in the future because it is not compatible with MDCI based MTRP. From spec effort perspective, we don’t think much effort is needed. As what we have agreed before, one of PDCCH repetition can still be used for scrambling, CRS rate matching, HARQ-Ack timing. For BD, the solution of proposal 5 can be reused, e.g. 3 BD is split into 2+1 for two PDCCH candidates respectively.  |

## **Additional issues requiring a reference candidate**

The following FL proposal was discussed in the previous meeting with majority support while some companies preferred more time for further study.

FL proposal: For the following purposes, the PDCCH candidate that ends later in time among the two linked PDCCH candidates is used as a reference

* For N timeline in the case that DL DCI does not schedule PDSCH but requests HARQ-Ack: SPS release DCI, SCell dormancy indication, requesting Type-3 HARQ-Ack codebook
* For SPS PDSCH cancelation timeline (14 symbols)
* For PUCCH resource overriding timeline (N3)
* For starting drx-InacitivityTimer
* For timeline to send PRACH in response to PDCCH order
* For PDSCH / AP-CSI-RS reception preparation time with cross carrier scheduling with different SCS’s for PDCCH and PDSCH / AP-CSI-RS, i.e., minimum scheduling delay Npdsch and Ncsirs

In addition, companies identified some similar additional issues listed below in their contributions:

* PHR timeline conditions for virtual versus actual PHR: ASUSTeK
* TPC application time window to determine whether a TPC command is applicable or not: OPPO
* CPU occupation duration for AP-CSI: Fraunhofer
* SRI refers to the SRS resource(s) transmitted prior to the PDCCH starting earlier in time: Fraunhofer

The issues listed above are similar in the sense that the same reference candidate can be used to resolve them. For all cases except the last one, the PDCCH candidate that ends later in time should be used as the reference based on the company proposals. Also, one company suggested a general proposal as below:

**General proposal**: For channels/signals scheduled by PDCCH repetition, the end of a PDCCH candidate that ends later in time among two linked PDCCH candidates is used as the DCI decoding time reference.

From moderator’s perspective, this proposal is helpful to avoid case-by-case discussions in the future if there are more of such cases. On the other hand, given that specification does not have a defined rule for DCI decoding timeline in general, and timeline values / conditions are not exactly the same for different cases, it may still be useful to list the cases identified by companies so far. For example, some of the cases above are not directly related to a scheduled channel/signals (SPS cancelation, PUCCH resource overriding) and some cases are not directly for DCI decoding time (DRX inactivity timer, CPU duration). Also, these rules are currently in different specs (some in 38.213, others in 38.214), and it is up to the editors how to capture them for Rel. 17 PDCCH repetition.

***FL Proposal 10:***

***For the issues involving a timeline for/related to DCI decoding, the PDCCH candidate that ends later in time among the two linked PDCCH candidates is used as a reference. This includes at least the following issues***

* ***For N timeline in the case that DL DCI does not schedule PDSCH but requests HARQ-Ack: SPS release DCI, SCell dormancy indication, requesting Type-3 HARQ-Ack codebook***
* ***For SPS PDSCH cancelation timeline (14 symbols)***
* ***For PUCCH resource overriding timeline (N3)***
* ***For starting drx-InacitivityTimer***
* ***For timeline to send PRACH in response to PDCCH order***
* ***For PDSCH / AP-CSI-RS reception preparation time with cross carrier scheduling with different SCS’s for PDCCH and PDSCH / AP-CSI-RS, i.e., minimum scheduling delay Npdsch and Ncsirs***
* ***For PHR timeline conditions for virtual versus actual PHR***
* ***For TPC application time window to determine whether a TPC command is applicable or not***
* ***For CPU occupation duration for AP-CSI***

***For the following issue, the PDCCH candidate that starts earlier in time among the two linked PDCCH candidates is used as a reference:***

* ***For determining the most recent transmission of SRS resource(s) identified by the SRI***

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | Support the proposal  |
| MediaTek | Support the proposal |
| Apple | Support the proposal |
| QC | Support the proposal. |
| Lenovo/MotM | Support the proposal |
| Fraunhofer IIS/HHI | Support the proposal |
| Fujitsu | Support the proposal. |
| OPPO | Support the proposal. |
| Xiaomi | Support the proposal |
| Samsung | Support the proposal |
| Spreadtrum | Support the proposal |
| InterDigital | Support the proposal.  |
| vivo | Support the proposal |
| ZTE | Support the proposal |

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

Multiped companies (MediaTek, Huawei/HiSilicon, Qualcomm, vivo, Samsung, Spreadtrum) described the complexity issues as a result of PDCCH repetition configuration that results in UE requiring to keep LLRs for too many candidates for too long. As an example, MediaTek provided the following figure to describe such issues:



The issue is mostly related to memory requirements at the UE side (especially for soft combining), and can be though as equivalent to LBRM for PDSCH HARQ buffer size. Even though the solution does not need to be as complicated as LBRM, it should address the complexity in various cases. For example, Qualcomm described some other cases that have similar issue when two different pairs of linked SS sets are considered (and not only among linked MO’s of a given pair of linked SS sets), or the case of only two linked MO’s in a given slot but with large number of linked candidates.

In terms of solutions, different companies may have different preferences. Some companies prefer the specification to prevent certain cases to be configured while other companies prefer more flexibility based on UE capability. For the latter case, for example, vivo mentioned that number of linked PDCCH repetition pairs in one slot can be subject to UE capability, or Samsung mentioned that number of MO’s between any two linked MO’s can be limited to a max number.

It may be first helpful to discuss if the issue should be addressed, and if yes, for which cases. Initial solutions that companies have in mind to address this issue can also be discussed. For this purpose, the following questions are asked:

***Question 1: Do you think the issue described above related to UE complexity / memory requirements needs to be addressed? If yes, which of the one or more following cases are relevant in your view:***

* ***Case 1: One pair of linked MO’s of one pair of linked SS sets in a given slot with large number of candidates.***
* ***Case 2: Multiple pairs of linked MO’s of one pair of linked SS sets in a given slot, where MO’s of the two SS sets are not interlaced (similar to Case 2 in the figure above)***
* ***Case 3: For two pairs of linked SS sets (e.g. SS sets 1 and 2 are linked, and SS sets 3 and 4 are linked), a MO of any of the SS sets (e.g. SS set 3) is in between two linked MOs of another two SS sets (e.g. SS sets 1 and 2).***

***Question 2: If the answer to Question 1 is yes, please describe how the issue should be addressed (e.g. restriction, UE capability, etc.)***

|  |  |
| --- | --- |
| Company | Comments |
| NTT Docomo | We agree to address the above issue.In our understanding, case2 and case3 need to be considered to address the issue. |
| MediaTek | We think this issue needs to be addressed. Otherwise, it would greatly increase the UE LLR buffer size. Case 2 and case 3 are relevant in our view. As we mentioned in our tdoc, this is our proposal. **Proposal: For linking monitoring occasions across the two SS sets that exist in the same slot:** * **The two SS sets have the same number of monitoring occasions within a slot and n-th monitoring occasion of one SS set is linked to n-th monitoring occasion of the other SS set**
* **The pair of monitoring occasions shall not have any monitoring occasion in between.**

Also, we are open to discuss further to resolve this issue with an alternative solution.  |
| Apple | We agree that there should be some LLR buffer size issue if UE wants to use soft combining. But the issue not only exists for the linked MO configuration, but also has exists for CA case. Even with the restriction like inter-laced pattern, if there are too many linked MO in multiple CCs, UE still needs to buffer many LLR. In addition, before we move into the details, can we conclude inter-slot repetition is not supported in Rel-17?  |
| QC | Q1: Yes. We think all Cases (1,2,3) are relevant and similar for complexity/memory requirements.Q2: We prefer a mechanism to limit the number of linked candidates on the fly at any given time instance. The max limit can be UE capability. Also, this should be AL-dependent as memory requirement for 2 linked AL-1 candidates is not the same as 2 linked AL-16 candidates. A similar mechanism as CPU occupation (for CSI) can be used here for PDCCH repetition.  |
| Lenovo/MotM | We are open for discussing this issue based on available restriction on maximum monitored candidate number per slot and on maximum non-overlapped CCE number per slot.  |
| LG | Q1: Yes for case 2 and 3 with soft combining.Q2: one simple way is put scheduling restriction suggested by MediaTek and we are also open to define simple UE capability, which is VIVO and Samsung suggested, if UE tries 3 BDs for two linked candidates. |
| Fraunhofer IIS/HHI | Q1: We prefer addressing the issue. All the aforementioned cases seem relevant to addressing memory requirements.Q2: We believe that different solutions may be applicable to different cases. We are open to UE capability reporting for the number of linked PDCCH candidates that can be decoded in a slot as well as timeline restrictions as proposed by MediaTek. |
| OPPO | For Q1：Yes. We think case 2 and case 3 should be considered. Add one more case. * Case 4: For a pair of linked SS sets (e.g. SS sets 1 and 2 are linked), one or more MOs of the SS sets (e.g. SS set 3, 4, …) are in between the linked Mos of two SS sets (e.g. SS sets 1 and 2).
* Maybe we can regard Case 4 as a special case of Case 3 if SS set 3/4 are not linked with any other SS sets.

For Q2: We think some restriction on the configuration of monitor occasion should be introduced, e.g., MTK’s proposal above, restriction on the span. |
| Xiaomi | Q1: yes. We think case 2 and case 3 with soft combining need to be considered to address this issue. Q2: it can be addressed by restricting the time location of two linked PDCCH candidates noted by other companies. |
| Samsung | For Q1: We believe at least case 2 and 3 should be discussed. For Q2: we think the approach based on UE capability can be a flexible way to implement a PDCCH repetition feature. Restriction by specification is also fine. |
| Spreadtrum | Q1: Yes. At least case2 and Case 3Q2: We prefer to restrict linked SS occasion’s pattern, for it is simple. |
| InterDigital | Q1: yes for case 2 and case 3 considering soft combining.Q2: it can be addressed through UE capability reporting.  |
| vivo | Comparing with R15, PDCCH repetition in R17 mainly affect the buffer capability of soft bits for combining given that the capability of BD/CCE is not changed. If chipset vendors think buffer capability play a central role for UE reception, two factors can be taken into account:1. restrict PDCCH repetition pattern e.g. case1 in the above figure, of course which is not flexible for NW’s configuration.
2. restrict PDCCH repetition number with flexible repetition pattern to assure priority of buffer capability
 |
| ZTE | Is this a serious issue? We even haven’t agreed inter-slot PDCCH repetition. That is, UE needs to buffer two PDCCH repetitions only within one slot. We don’t see much buffer issue here just because of less than one slot.  |

## **Other Issues**

The following table lists additional proposals / issues mentioned by companies.

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Summary of the proposal and moderator’s comment** |
| 1 | Inter-slot PDCCH repetition | Views expressed in the contributions:* Support: ZTE, NEC, Xiaomi, Intel

Moderator’s comment: The issue has been discussed before, and it would be good to decide in this meeting. Can be discussed in the next round depending on the progress. |
| 2 | Support for DCI formats 2\_x (CSS Type3), and other CSS types (Types 0/0A/1/2) in RRC connected | Convida, Ericsson, and Qualcomm propose to discuss some of the DCI formats 2\_x.Vivo and Lenovo/MotM proposed to discuss whether different CSS types (0/0A/1/2/) are supported for PDCCH repetition or not.Fraunhofer: QCL assumption for PDCCH with RA-RNTI and scheduled PDSCH with CFRA-based PDCCH orderModerator’s comment: At least some aspects of this has been discussed before (Type3), but there are also some new aspects. It would be good to decide what type(s) of CSS are supported in this meeting. Can be discussed in the next round depending on the progress. |
| 3 | Issues related to BFR | Apple proposed the following:* Support UE to report 2 new beams in BFRQ for PCell/SCell BFR, and after UE receives BFR response it can apply the 2 beams for reception of PDCCH repetition with 2 beams
* SS-BFR should not be linked with other SS for PDCCH repetitions

Moderator’s comment: At least for the second issue (SS-BFR), some discussions seem to be useful for clarification.  |
| 4 | The earliest time AP-CSI-RS resource can be received | Qualcomm proposes to clarify the restriction for receiving AP-CSI-RS in the case of PDCCH repetition.Moderator’s comment: This issue can be discussed after PDSCH mapping Type B given the similarities of the existing restrictions for PDSCH mapping type B and CSI-RS. |
| 5 | PDSCH mapping Type A | Qualcomm proposes to clarify the restriction for PDSCH mapping Type A in the case of PDCCH repetition.Moderator’s comment: This issue can be discussed later if needed. |
| 6 | Other restrictions for linking | Lenovo/MotM: Larger search space set ID is not expected to be configured for the search space set corresponding the first candidate between two linked search space set; Successive search space set ID configured for linked search space sets.Moderator’s comment: This issue can be discussed after clarifications on overbooking if needed. |
| 7 | SS set group switching | Qualcomm proposed to use the Rel. 16 SS set group switching mechanisms for more dynamic linking, or study how the two features can work together.Moderator’s comment: Can be discussed in the future if needed. |
| 8 | Single-TRP PDCCH repetition | Views expressed based on the contributions on whether two linked SS sets can be associated with the same CORESET or it should be restricted:* They can be associated with the same CORESET: Nokia/NSB, Intel, Qualcomm
* It should not be allowed: CATT, Ericsson

Moderator’s comment: The issue has been discussed before, and majority view was that there is no need to add a restriction and it can be up to gNB implementation.  |
| 9 | Overlapping of linked PDCCH candidates | CATT proposed that UE is not required to decode the candidates in this case.Moderator’s comment: The issue has been discussed before w/o a conclusion. Seems companies did not see the need for further discussions in this meeting. |
| 10 | Active BWP switching | Vivo proposed to consider relaxing the existing restriction for BWP switching (DCI should be received in the first 3 symbols of the slot), and corresponding timeline changes.Moderator’s comment: Issue was discussed in the previous meeting and most companies did not see the need to further discuss. |
| 11 | Allow for MAC-CE to update linking | CATT, Xiaomi, and MediaTek propose this.Moderator’s comment: The issue is already listed as FFS before, and most companies did not see the need in the previous meeting. |
| 12 | Support other frameworks for PDCCH reliability in addition to the agreed framework (Option 2 + Case 1 +Alt3) | Lenovo/MotMModerator’s comment: Discussed multiple times before. Majority view is that the agreed framework is enough. Also, it may be late for a new additional framework at this point. |

Please provide your comments. Moderator suggests to at least discuss Issues 1, 2, 3, and 4 above during the next rounds depending on the progress.

|  |  |
| --- | --- |
| Company | Comments |
| QC | In addition to issues 1-4, we prefer to also discuss at least issue 5 (PDSCH mapping type A) |

# **Detailed Proposals / Observations**

|  |  |
| --- | --- |
| Huawei, HiSilicon | Proposal 1: When UE reports 3 BDs for the linked candidates, it implies that UE supports soft combining. Proposal 2: For linked PDCCH candidates, UE can report the capability of supporting 3 BDs for the linked candidates. * If UE support the capability, gNB can configure 2 or 3 BDs for the linked candidates
* If UE does not support the capability, 2 BDs are assumed for the linked candidates

Proposal 3: For overbooking, the linked candidates are counted as a whole. Proposal 4: When one of the linked PDCCH candidates uses the same set of CCEs with an individual PDCCH candidate, and both are associated with the same DCI size, scrambling, and CORESET, support Option 1, i.e., the individual PDCCH candidate is not counted for monitoring. Proposal 5: When one of the linked PDCCH candidates uses the same set of CCEs with another linked PDCCH candidate, and both are associated with the same DCI size, scrambling, and CORESET, the linked PDCCH candidates containing the candidate with the highest SS set ID are not additionally counted. Proposal 6: For PDCCH repetition with two linked candidates and one candidate is dropped, support Option 1 for the cases {1,2,3,4,6}. Proposal 7: For TDM based PDCCH repetition scheme, the start of PDSCH can be the same as or later than the start of the earlier PDCCH repetition in time domain, i.e., Alt 3 is supported. Proposal 8: For multi-TRP based PDCCH repetition, when the TCI field is not present in the DCI, the default TCI state of the scheduled PDSCH is determined as follow:* When TCI states of PDSCH are activated and at least one TCI codepoint is associated with two TCI states, UE assumes that the two TCI states of the PDCCH are applied for PDSCH transmission.
* Otherwise, UE assumes the TCI state of the CORESET with lower ID (among the two CORESET of the PDCCH) is applied for PDSCH transmission.

Proposal 9: To identify two QCL-TypeD properties to be received for overlapped CORESETs, support to reuse legacy priority rule to identify the first QCL-TypeD properties, and then, identify the second QCL-TypeD according to one of the SS set that is linked with the SS set with the first QCL-TypeD.  |
| ZTE | Proposal 1-1: Support inter-span PDCCH repetition within one slot. Proposal 1-2: Support inter-slot PDCCH repetition.Proposal 1-3: UE reports capability either with BD number = 2 or = 3 (NOT both) for two linked PDCCH candidates* For UE capability report with BD number =3, gNB can configure either BD number = 2 or 3
* For UE capability report with BD number =2, UE further reports whether soft combining or individual detection is used
	+ gNB can configure either soft combining or individual detection for configuration of BD number = 2

Proposal 1-4: When two linked PDCCH candidates are in different spans or slots* For BD number =3, the BD numbers of the earlier and later PDCCH candidate are 1 and 2 respectively
* For BD number =2, the BD numbers of the earlier and later PDCCH candidate are 1 and 1 respectively

Proposal 1-5: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, support Option 1, i.e. the individual candidate is not counted for monitoring. Proposal 1-6: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), support Option 1, i.e. UE still monitors the linked candidate that is not dropped. Proposal 1-7: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition, for the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV, support Alt 1, i.e. the PDCCH candidate that starts later in time is used.  |
| vivo | 1. For number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, support
* UE reporting BD number 2 or 3 for the two PDCCH candidates
* Introducing RRC signaling to configure BD number of 2 or 3 if UE reports BD number 3.
1. support both Alt1 and Alt3 for PDSCH mapping type B and which Alt is supported can be subject to UE capability.
2. in case of PDCCH repetition, the retuned value of $d\_{1,1}$ is related to BD count of PDCCH decoding and overlapping pattern.
3. Confirm the working assumption by removing the FFS bullet.
4. support option1 for the issue about overlapping a linked candidate with and individual candidate.
5. Support aggregation level restriction to resolve the ambiguity for interpretation of detected DCI and RRC can indicate extra AL value1 and value2 for differentiating S-TRP and M-TRP.
6. Support Option1 and BD count is based on PDCCH repetition in Rel17.
7. UE can receive PDCCH candidates overlapped in time with different QCL-typeD based on UE capability and group beam pair for simultaneous reception
8. Take later PDCCH candidate in time as reference candidate to determine the timeline for HARQ-ACK feedback of PDCCH.
9. the timing for active BWP switching should be enhanced considering PDCCH repetition.
10. Inter-slot PDCCH repetition is not supported in Rel17.
11. support option2 for overbooking and virtual SS is introduced when BD number 3 is assumed.
12. number of linked PDCCH repetition pairs in one slot is subject to UE capability.
13. down select one option for PDCCH repetition in CSS.
 |
| Lenovo, Motorola Mobility | Proposal 1: Support to introduce non-integer number as candidate value for UE reporting on account of implicitly additional information for soft combining. Proposal 2: Support gNB optionally configuring the BD number for two linked PDCCH candidates. Proposal 3: Support Alt.1, i.e. the candidate that starts later in time as reference candidate for defining earliest time for PDSCH and reference symbol for SLIV. Proposal 4: Support the overlapping symbol defined as max{x, y} for defining $d\_{1,1}$ for PDSCH processing time, where x, y are overlapping symbol number between the first/second PDCCH and PDSCH, respectively.Proposal 5: Slightly prefer option 2, i.e. the candidate in a higher SS set ID is not counted for monitoring. Proposal 6: Support option 2, i.e. Both linked candidates are dropped if at least one of them is dropped, when one of linked PDCCH candidates is dropped. Proposal 7: Reuse Rel.15 priority rule, i.e. higher priority for common search space set and search space set with smaller ID, as much as possible for discussing enhancing existing QCL-TypeD priority rules for overlapping CORESETs.Proposal 8: Put the same monitoring priority for two linked search space sets for ePDCCH transmission with overlapping monitoring occasions.Proposal 9: Allocate PDCCH candidates with granularity of two linked search space sets in case of overbooking. Proposal 10: Use search space set with smaller ID as reference search space set to determine dropping priority for linked search space sets. Proposal 11: Make restriction for configuration of linked search space set if resource allocation granularity is individual search space set: 1. Larger search space set ID is not expected to be configured for the search space set corresponding the first candidate between two linked search space set; 2. Successive search space set ID configured for linked search space sets.Proposal 12: Support enhanced PDCCH with repetition transmission for common PDCCH, e.g. SIB, paging, in RRC connection state.Proposal 13: Support Option 3, i.e. separate DCIs that schedule the same PDSCH/PUSCH/RS/TB/etc or result in the same outcome.Proposal 14: For Option 3, each DCI is transmitted independently as a R15 PDCCH candidate in valid CORESET with the corresponding TCI.Proposal 15: Use sequence number to identify the DCIs serving the same purpose. Proposal 16: 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.  |
| Spreadtrum Communications | Proposal 1: Only value 2 is supported for the number of BDs for the two PDCCH candidates.Proposal 2: For PDCCH repetition, not support MAC-CE for linking two SS sets.Proposal 3: The monitor occasions for linked SS sets are placed in a time domain interlaced pattern within one slot.Proposal 4：The reference candidate is the one stars later in time for deciding the reference symbol for SLIV.Proposal 5：d is defined as the number of overlapping symbols of the scheduling PDCCH(s) and the scheduled PDSCH.Proposal 6：Confirm the working assumption below:* Working assumption: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.
* If the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable, PDSCH QCL assumption is based on the CORESET with lower ID among the first and second CORESETs
* FFS: Whether additional options are needed (e.g. to enable SDM/FDM/TDM PDSCH schemes w/o TCI field in the DCI)

Proposal 7：For reception with two different beams, we have the following options:* the 1st reference CORESET determined by Rel-15/16 rules among unlinked PDCCH repetitions
* the 2nd reference CORESET determined by Rel-15/16 rules among linked PDCCH repetitions

Proposal 8：Support option-2 where the candidate in a higher SS set ID is not counted for monitoring.Proposal 9：Support option-1 where UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate).Proposal 10: All the dropping cases should be considered for option-1. |
| Samsung | Proposal 1: Support Alt3 (the candidate that starts earlier in time) as a determination for a reference candidate among repetitive PDCCH candidates for scheduling PDSCH mapping type B.Proposal 2: Support Option 2 (i.e., The candidate in a higher SS set ID is not counted for monitoring) for the purpose of BD counting and interpretation of a detected DCI when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET.Proposal 3: Support Option 1 (UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules) if one of the linked candidates is not monitored (is dropped) due to Rel. 15/16 procedures.Proposal 4: Support PDCCH repetitions with different CORESETPoolIndex values based on the framework of option 2 + case 1 + Alt3.Proposal 5: Further study the PDCCH repetitions with different CORESETPoolIndex values based on the framework of option 2 + case 1 + Alt3 for the following aspects:1. PDSCH scrambling / CRS rate matching / HARQ-ACK as in the previous agreement
2. Which kind of PDSCH can be scheduled? Single PDSCH or NC-JT PDSCHs or both (if so, whether/how to switch?)
	1. Indicating TCI state field / MAC-CE operation
	2. Indicating DM-RS field
	3. Indicating HARQ process ID field and NDI field
	4. Whether/how to apply for activation/deactivation on CG or SPS
3. FFS: other aspects are not precluded.

Observation 1: Restriction/limitation on the amount of BD/CCE corresponding to repetitions needs to be considered to acknowledge increased/duplicated processing burden with soft combining. Restriction/limitation on the amount of BD/CCE between two repetitions needs to be considered to acknowledge increased memory budget due to lasting impact of unresolved first repetitions.Proposal 6: For intra-slot repetition, when two SS sets with $M$ MOs in the slot are linked together, limit the maximum number of MOs between any two linked MO #$i$ of the first SS set and MO#$i$ of the second SS set to a maximum number.Proposal 7: For inter-span PDCCH repetition, further study how to count the PDCCH candidate towards the BD/CCE limit, and perform SS overbooking/dropping.Proposal 8: 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. |
| CATT | Proposal 1: * MAC-CE can be used additionally to update linkage of SS sets. The following updating methods can be considered,
	+ More than two SS sets are linked by RRC signaling, and MAC-CE can activate/update two of them to perform PDCCH repetition.
	+ More than two SS sets are linked by RRC signaling, and MAC-CE can activate/update one of them to perform single PDCCH transmission.
	+ Two SS sets are linked by RRC signaling, and MAC-CE can activate/update one of them to perform single PDCCH transmission.

Observation: * Agreed monitoring occasion linking method may lead to inter-span PDCCH repetition.

Proposal 2:* If a UE is configured with per span PDCCH monitoring (r16monitoringcapability), mechanism might be needed to avoid inter-span repetition. Otherwise, inter-span repetition can be supported.

Proposal 3:* Soft combining should be supported for linked PDCCH candidates with either one of the options:
	+ Option 1: A value between 1 and 2 is added to the candidate values of BD units.
	+ Option 2: one of the agreed candidate values imply that UE supports soft combining.

Proposal 4:* There is no need to introduce additional non-integer numbers for Assumption 3 and 4.

Proposal 5:* UE can report one number as required number of BDs in UE capability reporting, and RRC signaling configures a number which is no larger than the reported UE capability.

Proposal 6: * Two linked PDCCH candidates can be treated as one unit to judge whether this unit can be monitored or not.
	+ Besides, the unit can be two linked monitoring occasions, two linked aggregation levels.

Proposal 7: * When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, Option 3 is adopted.
	+ Option 3: The candidate associated with SS set(s) with lower priority is not counted for monitoring, where for two linked SS sets, the priority is according to one of the two SS sets with a lower SS set ID.

Proposal 8:* For PDCCH repetition with two linked candidates, if due to Rel-15/16 procedures, one of the linked candidates is not monitored (is dropped), the other PDCCH candidate is also dropped (i.e. Option 2).

Proposal 9: * UE does not expect CCEs for the linked PDCCH candidates to be overlapped.

Proposal 10:* Before PDCCH monitoring rule is discussed, first discuss whether to support multiple pairs of linked SS sets in overlapping PDCCH monitoring occasions, or the feature that PDCCH repetition and CA are configured simultaneously.

Proposal 11: * Linked SS sets which correspond to different CORESETs with different QCL-TypeD properties can be used to determine monitored CORESETs.

Proposal 12: * The PDCCH candidate which starts later in time (i.e. Alt1) among the two linked PDCCH candidates in the time domain is used as reference symbol for SLIV when ReferenceofSLIV-ForDCIFormat1\_2 is configured.

Proposal 13: * If the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable, and PDSCH repetition is configured or performed, PDSCH QCL assumption is based on the CORESETs of both linked PDCCH candidates.

Proposal 14: * PDCCH repetition can be used with multi-DCI based multi-TRP. In this case, the following methods can be considered for PDSCH transmission:
	+ Two PDCCHs schedule one PDSCH with one TCI state.
	+ Two PDCCHs schedule two same PDSCHs with one or two TCI states.

Proposal 15:* For PDSCH scrambling, a reference PDCCH candidate (the one with the lowest CORESET ID) or a reference scrambling identity can be defined to avoid ambiguity.

Proposal 16: * For CRS rate matching,
	+ If one PDSCH is scheduled, a reference PDCCH candidate (the one with the lowest CORESET ID) or a reference CRS pattern can be defined to avoid ambiguity.
	+ If two same PDSCHs are scheduled, there is no ambiguity.

Proposal 17: * For HARQ-ACK feedback in PDCCH repetition with multi-DCI framework, UE does not expect to be configured with parameter ackNackFeedbackMode.

Proposal 18:* In single-TRP PDCCH repetition, Option 1 is supported.

Option 1: Add a restriction that two linked SS sets cannot be associated with the same CORESET. |
| Fujitsu | Proposal 1: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, option 1 is preferred:* The individual candidate is not counted for monitoring
	+ Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).

Proposal 2: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with ReferenceofSLIV-ForDCIFormat1\_2, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), Alt-1 is preferred:
	+ A reference candidate is the candidate that starts later in time

Proposal 3: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition, * the PDCCH candidate that starts later in time is used for the determination of d1,1.

Proposal 4: Support to enable SDM/FDM/TDM PDSCH schemes w/o TCI field in the DCI.Proposal 5: Do not support PDCCH repetitions in multi-DCI based multi-TRP.Proposal 6: Do not support any enhancement for the purpose of single-TRP PDCCH repetition. |
| FUTUREWEI | Proposal 1: For the BD count, take into consideration the one-outage scenario in which only one transmission has gone through for a M-TRP transmission, and exactly which one cannot be known a priori to the gNB or UE.Proposal 2: Clarify if simultaneous S-TRP/M-TRP transmissions on overlapped time-domain resources are supported or not.Proposal 3: For PDCCH repetition with two linked candidates, if one of the linked candidates is not monitored (is dropped):* Support Option 2: Even the candidate that is not dropped is not monitored (Both linked candidates are dropped if at least one of them is dropped)
* The dropping of one of the linked candidates may be due to Rel-15/16 rules (e.g., Case 1 ~ Case 6) or new Rel-17 rules.

Proposal 4: For overlapped S-TRP/M-TRP candidates and ambiguity issue, support revised Option 3: For the 3 candidates with 3 SS set IDs, UE is not expected to monitor a candidate not with the lowest SS set ID and not linked to a candidate with the lowest SS set ID.Proposal 5: For the BD count, clarify the implementation assumption that a pre-determined BD order has to be adopted by the UE.Proposal 6: For the BD count, clarify whether UE reporting soft-combining capability is considered as disclosing receiver implementation or not.Proposal 7: For the BD count for Option 2 + Case 1 with up to two PDCCH candidates:* If UE reports 2, always 2 BDs are assumed;
* If UE reports 3, always 3 BDs are assumed;
* Reporting of 3 implies that the UE supports soft combining.
 |
| NEC | Proposal 1: For PDSCH with mapping Type B, support Alt 3 (The candidate that starts earlier in time). Proposal 2: Option 1 (The individual candidate is not counted for monitoring) should be supported when one of the linked PDCCH candidates uses the same set of CCEs as an individual PDCCH candidate. Proposal 3: Option 1 (UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)) should be supported when one of the linked PDCCH candidates is not monitored. Proposal 4: PDCCH repetition should be jointly considered with other features, for example, in case of dynamic beam indication with unified TCI framework in agenda item 8.1.1, and the UE behavior in case of TRP-specific BFR in agenda item 8.1.2.3.Proposal 5: Support inter-slot PDCCH repetition. |
| OPPO | Proposal 1: Support to report only one number as required number of BDs for two linked PDCCH candidates.Proposal 2: Reuse Rel.15 overbooking rule and allocate separate number of BD to two PDCCH candidates respectively that are linked for PDCCH repetition.Proposal 3: Assign 1 BD for PDCCH candidate in SS with lower SS set ID and assign the remaining BD for linked PDCCH candidate in another SS with higher SS set ID.Proposal 4: Support to specify the PDCCH candidate starts later in time as a reference for the purpose of the earliest time that the PDSCH can be scheduled as well as reference symbol of SLIV.Proposal 5: To define d1,1 $d\_{1,1}$for PDSCH processing time for UE processing capability 2, support d1,1=3 when all the following conditions are met:* one of the PDCCHs is in a 3-symbol CORESET in linked PDCCH repetition
* the PDSCH and the 3-symbol CORESET have the same starting symbol
* the number of PDSCH symbols allocated is 2

otherwise, d1,1 is determined from the maximum overlapping symbols between linked PDCCH candidates and PDSCH and number of PDSCH symbols.Proposal 6: For a UE supporting reception with two different beams, to support time-overlapping PDCCH repetitions in FR2, identify the two QCL-Type D properties for multiple overlapping CORESETs according to the increasing order of CSS set first and then USS set.Proposal 7: Support Option 2 when one of the linked PDCCHs uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI:The candidate with a higher SS set ID is not counted for monitoring and interpretation of detected DCI depends on which candidate is not counted.Proposal 8: For two linked SS sets used for PDCCH repetition, support setting adjacent SS set IDs only.Proposal 9: Support Option 1, that is, UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel.17 PDCCH rules for PDCCH repetition with two linked candidates when one of the linked candidates is not monitored.Proposal 10: If one of the linked candidates is dropped, only 1 BD is counted for the remaining PDCCH candidate.Proposal 11: For PUSCH/PUCCH/SRS, if the scheduling/triggering PDCCH is configured with repetition, the last PDCCH among PDCCH repetitions is applied to determine the accumulated windows for group common TPC.Proposal 12: If repetition is configured to the PDCCH carrying group common TPC command, the last PDCCH among PDCCH repetitions is used to determine whether the TPC command is applicable or not. |
| Qualcomm Incorporated | Proposal 1: Support reusing SS set group switching mechanisms for dynamic SS set linking in the case of PDCCH repetition (applies to a UE that supports SS set group switching).Proposal 2: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), support Option 1:* UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)
* The following Rel. 15/16 rules are applicable for this purpose:
	+ Case 1: Overlap with SSB
	+ Case 2: Overlap with rate matching resources: RateMatchPattern, lte-CRS-ToMatchAround, or LTE-CRS-PatternList-r16, availableRB-SetPerCell-r16
	+ Case 3: Due to TDD DL/UL related conflicts: Overlap with semi-static / dynamic UL symbols or overlap with PRACH
	+ Case 4: QCL-TypeD prioritization rule among CORESETs result in one of the linked candidates not being monitored
	+ Case 5: Overbooking results in one of the linked candidates not being monitored
* This does not impact the BD count.

Proposal 3: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, support Option 1:* The individual candidate is not counted for monitoring
	+ Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).
* The max limit on number of such overlaps is up to UE capability.
	+ FFS: The details of UE capability

Proposal 4: Study mechanisms to address the UE complexity related to memory requirements with respect to PDCCH repetition configurations across one or more pairs of linked SS sets with one or more MO’s within a slot. * One possible mechanism is to define a processing unit for any two linked PDCCH candidates (analogous to Rel. 15 CPU occupation for CSI computation complexity).

Proposal 5: The default behaviour for number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition is to assume 2 BDs.* If UE indicates 3 BDs as required number of BDs for two linked candidates, network can configure the UE via RRC signalling to count two linked candidates as 3 BDs. If not configured, 2 BDs are assumed.

Proposal 6: When two linked PDCCH candidates are counted as three BDs, for overbooking in the PCell for USS, the third BD is counted as part of SS set with higher index among the two linked SS sets. Proposal 7: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with ReferenceofSLIV-ForDCIFormat1\_2, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), a reference candidate is used. Select one among the following:
	+ Alt1: The candidate that starts later in time
* $d\_{1,1}$$d\_{1,1}$ for PDSCH processing time is determined by considering the PDCCH candidate that results in larger d1,1 value.

Proposal 8: For AP-CSI-RS scheduled by two PDCCH candidates that are linked for repetition, the UE does not expect that the AP-CSI-RS is transmitted before the first symbol of the PDCCH candidate that starts later in time.Proposal 9: If two linked PDCCH candidates schedule a PDSCH with mapping Type A in a same slot, both linked PDCCH candidates are expected to be contained within the first three symbols of the slot.Proposal 10: Confirm the working assumption in the agreement above: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.Proposal 11: When CORESETPoolIndex value is configured for one or more CORESETs, two linked PDCCH candidates are not expected to be associated with different CORESETPoolIndex values.Proposal 12: There is no need for restrictions with respect to CORESET(s) associated with two linked SS sets: Same CORESET as well as different CORESETs with same TCI state should be allowed.* When same CORESET is used, monitoring occasions of the two linked SS sets should be non-overlapping in time.

Proposal 13: For the following timelines and in the case of PDCCH repetition, the last symbol of the PDCCH candidate that ends later in time among the two linked PDCCH candidates is considered:* When DL DCI does not schedule PDSCH but triggers HARQ-Ack transmission: Timeline N for SPS release DCI [38.213, Section 10.2], SCell dormancy indication w/o scheduling PDSCH [38.213, Section 10.3], requesting Type-3 HARQ-Ack codebook w/o scheduling PDSCH [38.213, Section 9.1.4]
* PUCCH resource overriding timeline N3 [38.213, Section 9.2.3]
* Timeline to send PRACH in response to PDCCH order [38.213, Section 8.1]
* PDSCH / AP CSI-RS reception preparation time with cross carrier scheduling with different SCS’s for PDCCH and PDSCH / AP CSI-RS, i.e., minimum scheduling delay Npdsch and Ncsirs [38.213, Section 5.5 and 5.2.1.5.1a].

Proposal 14: When monitoring DCI format 2\_1 or 2\_4 in two PDCCH candidates that are linked for PDCCH repetition, UE determines the set of symbols that interrupted transmission indication or cancelation indication is applied to based on a reference PDCCH candidate, which is* For DCI format 2\_1: The PDCCH candidate that starts earlier in time.
* For DCI format 2\_4: The PDCCH candidate that ends later in time.

Proposal 15: For a UE supporting simultaneous reception with two different beams and when configured with PDCCH repetitions in FR2, among multiple overlapping CORESETs in one CC or for intra-band CA:* The first CORESET / QCL-TypeD property is determined based on Rel. 15 priority rules (priority is first wrt CSS vs USS, next serving cell index, next SS set index)
* The second CORESET / QCL-TypeD property is determined as follows:
	+ If there are time-domain overlapping PDCCH repetitions such that a first repetition is in a CORESET with the first determined QCL-TypeD property (either the first determined CORESET or another CORESET with the same beam), UE determines a second QCL-TypeD property as the QCL-TypeD of the CORESET associated with the second repetition.
		- If there are multiple such pairs of first/second repetitions as described above, the Rel. 15 priority rule is used for determination of the second QCL-TypeD property.
	+ Else, the second QCL-TypeD is determined based on the Rel. 15 rule by excluding the first determined CORESET and any other CORESET with the same beam as the first determined QCL-TypeD property.
* The UE monitors PDCCH in the first and second determined CORESETs and in any other CORESETs having the same QCL-TypeD properties as the first or the second determined QCL-TypeD properties.
 |
| CMCC | Proposal 1: UE could only report one candidate value as required number of BDs for two PDCCH candidates that are linked for PDCCH repetition.Proposal 2: Network could take 2 as required number of BDs for the two PDCCH candidates when UE don’t report any candidate value.Proposal 3: Support using the candidate that starts later in time as the reference PDCCH candidate for PDSCH type B (Alt1).Proposal 4: Consider the linkage of SS sets when identifying two QCL-Type D properties for multiple overlapping CORESETs.Proposal 5: The individual candidate might not be counted for monitoring (Option 1) when a linked candidate is overlapped with an individual candidate.Proposal 6: If due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), UE should still monitor the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate) (Option 1). |
| Fraunhofer IIS, Fraunhofer HHI | Proposal 1: The UE’s capability of soft-combining when decoding DCI transmitted on multiple PDCCH candidates shall be reported to the gNB explicitly, or implicitly via the value(s) reported for BD count.Proposal 2: Support PDCCH repetitions with PDCCH candidates associated with different CORESETpoolIndex values.Proposal 3: When the DCI is transmitted via PDCCH repetition with the PDCCH candidates associated with two different CORESETpoolIndex values, for PUCCH resource determination for HARQ-Ack when the corresponding PUCCH resource set has a size larger than eight, the starting CCE index and number of CCEs in the CORESET of the PDCCH candidate associated with the lowest CORESETpoolIndex are used.Proposal 4: When DCI is transmitted via PDCCH repetition with the PDCCH candidates associated with two different CORESETpoolIndex values, the PDSCH scrambling and CRS-rate-matching pattern may be determined based on the lowest CORESETpoolIndex value associated with the PDCCH candidates.Proposal 5: For the determination of the CPU occupation timing for the following cases, the PDCCH starting later in time is used as a reference: * Aperiodic or semi-persistent CSI report CPU occupation when the CSI report quantity is not set to ‘none’
* Aperiodic CSI report CPU occupation when the CSI report quantity is set to ‘none’

Proposal 6: When PUSCH is scheduled by a PDCCH comprising an SRI indication, the SRI refers to the SRS resource(s) transmitted prior to the PDCCH starting earlier in time.Proposal 7: For the purpose of determination of the offset value for sidelink transmissions scheduled by a DCI associated with multiple PDCCH candidates, the PDCCH candidate that ends later in time shall be taken as the reference PDCCH candidate.Proposal 8: The reception of a PDCCH order that triggers contention-free random access procedure for SpCell in multiple PDCCH candidates must be clarified.Proposal 9: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, choose option 3:* Option 3: The candidate associated with SS set(s) with lower priority is not counted for monitoring, where for two linked SS sets, the priority is according to one of the two SS sets with a lower SS set ID
	+ Interpretation of the detected DCI depends on which candidate is not counted (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).
	+ If any one of the PDCCH candidates among the linked PDCCH candidates is associated is dropped, then the other PDCCH candidate is also dropped.

Proposal 10: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), Option 2: Even the candidate that is not dropped is not monitored (Both linked candidates are dropped if at least one of them is dropped) |
| Apple Inc. | Proposal 2-1: For QCL-TypeD collision handling, support to determine the QCL-TypeD based on the priority for each group of beams, where the beams in a group can be received by UE simultaneously* For each group of beams, the priority is determined by the corresponding SS with highest priority

Proposal 2-2: UE shall not expect the linked SS sets associated with CORESETs with different CORESETPoolIndex.Proposal 2-3: For PCell/SCell BFR, support UE to report 2 new beams in BFRQ for PCell/SCell BFR, and after UE receives BFR response it can apply the 2 beams for reception of PDCCH repetition with 2 beams.Proposal 2-4: SS-BFR should not be linked with other SS for PDCCH repetitions.Proposal 2-5: Support CORESET-BFR to be associated with SS other than SS-BFR.Proposal 2-6: Support to configure 2 TCI states for CORESET0 for PDCCH repetition with non-SFN scheme.Proposal 2-7: For PDSCH mapping TypeB, the scheduling restriction should be counted based on Alt1 (The candidate that starts later in time).Proposal 2-8: For PDSCH mapping TypeB, d1,1 should be calculated based on the following scheme* The number of overlapping symbols of scheduling PDCCH and scheduled PDSCH is counted based on the 2 PDCCH repetitions and a symbol should be double counted when it contains 2 scheduling PDCCH and scheduled PDSCH
* For UE processing capability 2, if the number of PDSCH symbols allocated is 2, d1,1 is equal to the max{number of symbols for both CORESETs starting from the PDSCH symbol, number of overlapping symbols of PDCCH and PDSCH}

Proposal 2-9: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, Option 1 (The individual candidate is not counted for monitoring) is slightly preferred.Proposal 2-10: For PDCCH repetition with two linked candidates, if one of the linked candidates is dropped, the other linked candidate should be dropped. |
| LG Electronics | Proposal 1: Considering RAN 4 test requirement for 2 BD case, RAN 1 needs to decide whether 2 BD means two separate decoding or one individual decoding and one soft combining.Proposal 2: Equal or smaller BD number than what UE reports for the two linked PDCCH candidates should be configured by gNB.Proposal 3: For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV, reference candidate should be the candidate that starts later in time.Proposal 4: For a SS set pair, if one of linked candidates is not monitored the number of BD for the two linked candidates should be assumed one, not what UE reports, e.g., 2 or 3.Proposal 5: If TCI field is not present in DCI and the scheduling offset is equal to or larger than timeDurationForQCL,* if at least one code point is configured with two TCI states, the two TCI states corresponding to the two CORESETs is applied for MTRP PDSCH transmission.
* otherwise, the TCI state of the lower ID CORESET among the two CORESETs is applied for STRP PDSCH transmission

Proposal 6: For a UE supporting reception with two different beams, first priority CORESET and second priority CORESET can be selected based on current priority rule for CORESET collision. Additional priority rule can be introduced to provide CORESET for PDCCH repetition with higher priority.Proposal 7: If one of the linked PDCCH candidates uses the same set of CCEs and is associated with the same DCI size, scrambling, and CORESET as an individual PDCCH candidate, which candidate is not counted for monitoring is determined based on SS set ID (i.e., Option 2 or 3).* If one of the linked PDCCH candidates is not counted for monitoring, the number of BD for the two linked candidates should be assumed one, not what UE reports, e.g., 2 or 3.

Proposal 8: Support different CORESET pool index association for CORESETs for PDCCH repetition. |
| NTT DOCOMO, INC | Proposal 2-1:* When M-TRP PDSCH scheme is enabled by higher layer signaling, if a PDSCH is scheduled by a DCI in PDCCH candidates that are linked for repetition, and if the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL, two TCI states of the two linked CORESETs can be used as two default beams for PDSCH.

Proposal 2-2:* At least when UE reports required number of BDs as 3, it implies that UE supports soft combining.

Proposal 2-3:* When UE reports required number of BDs as 3, RRC can configure number of BDs as 2 or 3.

Proposal 2-4:* With Rel-17 M-TRP PDCCH repetition, consistent rules should be applied to determine priority among PDCCH candidates/CORESETs/SS sets for the following issues.
	+ QCL-typeD collision handling
	+ Overbooking
	+ BD counting of two PDCCH candidates with same set of CCE, same DCI size, scrambling, CORESET

Proposal 2-5:* For QCL-typeD collision handling, apply following priority rule for time-overlapping PDCCH repetition.
	+ CSS > USS; serving cell with lower cell ID > higher cell ID; linked SS set > individual SS set; Among linked SS sets, a pair of SS sets with lower SS set ID > higher SS set ID where priority of a pair of linked SS sets is according to one of the SS sets with lower SS set ID. Among individual SS sets, SS set with lower SS set ID > higher SS set ID

Proposal 2-6:* For overbooking, apply following priority rule for intra-slot/span PDCCH repetition.
	+ CSS>USS; linked SS set > individual SS set; Among linked SS sets, a pair of SS sets with lower SS set ID > higher SS set ID where priority of a pair of linked SS sets is according to one of the SS sets with lower SS set ID. Among individual SS sets, SS set with lower SS set ID has > higher SS set ID
	+ Two linked SS sets are counted and allocated together.

Proposal 2-7:* For BD counting of two PDCCH candidates with same set of CCE, same DCI size, scrambling, CORESET, apply following priority rule for intra-slot/span PDCCH repetition.
	+ When one of the linked PDCCH candidates and one individual PDCCH candidate overlap, the individual candidate is not counted
	+ When one of the linked PDCCH candidates and one of another pair of PDCCH candidates overlap, the candidate associated with SS set(s) with lower priority is not counted for monitoring; the priority follows lower SS set ID >higher SS set ID where for two linked SS sets, the priority is according to one of the two SS sets with a lower SS set ID
 |
| Xiaomi | Proposal 1: To decide the TCI state for each of two SS sets associated with a same CORESET by predefined rule for Alt 3.Proposal 2: To design one signaling for TCI state indication of two CORESETs for Multi-TRP PDCCH with Alt 3. Proposal 3: Support some candidate values implying that UE supports soft combining.Proposal 4: Slightly prefer Option 3 When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate.Proposal 5: Slightly prefer Option 1 if one of the linked candidate is not monitored due to Rel. 15/16 procedures.Proposal 6: Suggest to study the spatial setting for the PUCCH resource without PUCCH-SpatialRelationInfo.Proposal 7: Support both intra-slot and inter-slot Multi-TRP PDCCH transmission with two as the maximum repetition number.Proposal 8: Support MAC CE to activate/deactivate each linked SS set pair to achieve dynamical switching between Multi-TRP PDCCH transmission and single TRP PDCCH transmission.Proposal 9: Consider to configure same priority to the two linked SS sets based on the SS set with lower SS set ID for identification of two QCL Type D for monitoring overlapped CORESETs. |
| Convida Wireless | *Proposal 1:* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV, the reference candidate is the candidate that later in time (Alt1).*Proposal 2:*  If the TCI field isn’t present in the DCI and the scheduling offset is equal to or larger than timeDurationForQCL, support using the activated TCI states of both CORESETs for PDSCH reception if multi-TRP PDSCH is configured.*Proposal 3:* Support single-TRP PDCCH repetition using the agreed framework.*Proposal 4:* Support Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate). *Proposal 5:* Support PDCCH repetition of DCI formats 2\_x.  |
| Nokia, Nokia Shanghai Bell | Proposal 1: Support S-TRP PDCCH repetition based on M-TRP PDCCH repetition framework with two linked SS sets are associated with one CORESET. Observation 1: For number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, the UE reporting more numbers as required number of BDs for the two PDCCH candidates is not required and such enhancements adding more specification effort without clear benefits. Proposal 2: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with *ReferenceofSLIV-ForDCIFormat1\_2*, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), a reference candidate is used. Select the following:
	+ Alt1: The candidate that starts later in time

Proposal 3: For a UE supporting reception with two different beams, enhance existing QCL-TypeD priority rules for overlapping CORESETs. Select one from the following, * *Option 1:* select two QCL-TypeD based on extended Rel-15/16 mechanism by conditioning the selection of second QCL-TypeD to linking of CORESETs.
* *Option 2:* select two QCL-TypeD based on extended Rel-15/16 mechanism without any consideration of linking of CORESETs.

Proposal 4: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, select Option 1: * Option 1: The individual candidate is not counted for monitoring
	+ Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).

Proposal 5: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), select Option 1. * Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)
* The following Rel. 15/16 rules are applicable for this purpose:
	+ Case 1: Overlap with SSB
	+ Case 2: Overlap with rate matching resources: RateMatchPattern, lte-CRS-ToMatchAround, or LTE-CRS-PatternList-r16, availableRB-SetPerCell-r16
	+ Case 3: Due to TDD DL/UL related conflicts: Overlap with semi-static / dynamic UL symbols or overlap with PRACH
	+ Case 5: Overbooking results in one of the linked candidates not being monitored

Case 6: Overlap with reserved PRB(s) and OFDM symbol(s) indicated by DCI format 2\_1 where UE may assume no transmission intended for the UE |
| TCL communication | Proposal 1: When a linked candidate overlapping with an individual candidate, support Option 1, i.e., the individual candidate is not counted for monitoring.Proposal 2: For the reference PDCCH candidate for ACK/NACK in response to a SPS PDSCH release, the PDCCH candidate ending later in time is preferred. |
| Ericsson | [Proposal 1 In case of PDCCH repetition, UE can report “2” or “2+3” BD as a UE capability where “2” is the default.](#_Toc79186626)[Proposal 2 For a UE that support 3 BDs, the network explicitly configures the UE to use 3 BDs using RRC signaling. Default is 2 BD (no signaling needed)](#_Toc79186627)[Proposal 3 If 3 BD is configured, then the UE performs both selective decoding and soft combining of the two linked PDCCH candidates.](#_Toc79186628)[Proposal 4 For overbooking detection, half of the configured BDs is counted for each of the two PDCCH candidates in two linked SS sets.](#_Toc79186629)[Proposal 5 In case of overbooking, Rel-15 SS set dropping rules are applied.](#_Toc79186630)[Proposal 6 In case of PDCCH repetition, for type B PDSCH scheduled by DCI format 1\_2, the starting symbol S0 is associated with the PDCCH candidate starting earlier in time.](#_Toc79186631)[Proposal 7 In case of PDCCH repetition and for type B PDSCH scheduled by DCI format 1\_2, for d1,1, determination purpose, PDSCH symbols between the earliest and latest symbols of the PDCCH candidates in time are considered overlapping with the PDCCH.](#_Toc79186632)[Proposal 8 Confirm the working assumption that the UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.](#_Toc79186633)[Proposal 9 Option 1 (UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)) is preferred and one BD is counted.](#_Toc79186634)[Proposal 10 When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, Option 3 (the candidate associated with SS sets(s) with lower priority is not monitored) is slightly preferred.](#_Toc79186635)[Proposal 11 Confirm the working assumption that the same configuration is expected with respect to presence of TCI field in DCI in two linked CORESETs.](#_Toc79186636)[Proposal 12 For a UE supporting simultaneous reception with two different beams, when multiple CORESETs overlap in time, linked CORESETs are prioritized over unlinked CORESETs for PDCCH monitoring.](#_Toc79186637)[Proposal 13 No enhancement is needed for BWP switching in case of PDCCH repetition.](#_Toc79186638)[Proposal 14 For channels/signals scheduled by PDCCH repetition, the end of a PDCCH candidate that ends later in time among two linked PDCCH candidates is used as the DCI decoding time reference.](#_Toc79186639)[Proposal 15 MAC CE for linking SS sets is not supported.](#_Toc79186640)[Proposal 16 A specification change to introduce Intra-slot repetition to a single TRP is not pursued.](#_Toc79186641)[Proposal 17 DCI Format 2-2/2-3 are also supported by multi-TRP based PDCCH enhancements.](#_Toc79186642) |
| InterDigital, Inc. | Proposal 1: For the number of BDs, we make the following proposals: * Only a single value BD=2 should be supported,
* Soft-combining capability should be indicated explicitly,

Proposal 2: Support Alt1: The candidate that starts later in time. Proposal 3: Confirm the working assumption: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI. Proposal 4: SDM/FDM/TDM PDSCH schemes are disabled when the PDCCH does not contain a TCI field in the DCI.Proposal 5: Support Option 2 or Option 3.  |
| MediaTek Inc. |  Proposal 1: When one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET, for the purpose of BD counting and interpretation of a detected DCI, select one option among the following in RAN1#105-e:• Option 1: The individual candidate is not monitored ~~counted for monitoring~~ o Interpretation of the detected DCI is based on Rel. 17 PDCCH repetition rules (wrt reference PDCCH candidate).• Option 2: The candidate in a higher SS set ID is not monitored ~~counted for monitoring~~o Interpretation of the detected DCI depends on which candidate is not monitored ~~counted~~ (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).o FFS: Impact to the other linked PDCCH candidate• Option 3: The candidate associated with SS set(s) with lower priority is not monitored ~~counted for monitoring~~, where for two linked SS sets, the priority is according to one of the two SS sets with a lower SS set IDo Interpretation of the detected DCI depends on which candidate is not monitored ~~counted~~ (either based on Rel. 15/16 rules or based on Rel. 17 PDCCH repetition rules).• FFS: Impact to the other linked PDCCH candidateProposal 2: For linking monitoring occasions across the two SS sets that exist in the same slot: * The two SS sets have the same number of monitoring occasions within a slot and n-th monitoring occasion of one SS set is linked to n-th monitoring occasion of the other SS set
* The pair of monitoring occasions shall not have any monitoring occasion in between.

Proposal 3: For number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, do not introduce any default behaviour, the capability of soft combining, and the additional candidate values.Proposal 4: If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with ReferenceofSLIV-ForDCIFormat1\_2, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), the candidate that starts later in time is used as a reference candidate

Proposal 5: For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), support Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)* Note: there is no impact to BD count.

Proposal 6: Introduce new MAC CE to activate/deactivate the association of two search space sets for PDCCH repetition. |
| Intel Corporation | Proposal-1: Support Rel-15 mechanism of prioritizing a candidate based on SS set-ID in case of candidate overlap with the same set of CCEs, associated with the same DCI size, scrambling, and CORESET (options 2 or 3). It is not desirable to place restrictions on the number of such allowed overlaps. Proposal-2: If one of the linked candidates is not monitored (is dropped), both linked candidates are dropped.Proposal-3: For the number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, better to support one number (and the same one number for a given UE). No need for UE reporting of soft-combining capability.Proposal-4: There is no need to add restrictions to disallow single TRP PDCCH repetitionsProposal-5: Support using the PDCCH candidate that starts later in time as a reference candidate for a linked PDCCH scheduling a Type B PDSCHProposal-6: For PDCCH repetition, support identifying first and second priority CORESETs using existing prioritization rules that are overlapping in the same symbolProposal-7: For multi-DCI mTRP operation, extend the Rel-15 PDCCH prioritization technique by specifying the prioritization operation within the set of CORESETs associated with the same value of CORESETPoolIndexProposal-8: For multi-DCI multi-TRP, PDCCH repetition could be allowed within the same CORESETPoolIndex value.Proposal-9: Support inter-slot mTRP PDCCH repetition that allows joint scheduling of PDCCH across multiple slots at the gNB to reduce blocking probability (co-existing with intra-slot repetition) |
| ASUSTeK | Proposal 1: Confirm the working assumption with update that the UE expects the same configuration for the first and second CORESETs wrt presence and size of TCI field in DCI. Proposal 2: Regarding SPS PDSCH cancelation by scheduled PDSCH, latter PDCCH candidate among the two linked PDCCH candidates in time domain is proposed as the reference PDCCH candidate. Observation 1: According to current standard, whether a PHR for a serving cell is based on actual transmission or reference format is based on whether there is uplink grant until and including the PDCCH monitoring occasion where the UE detects the first DCI format scheduling an initial transmission of a transport block since a PHR was triggered.Observation 2: The first (earliest) DCI format could be associated to mTRP PDCCH, and reference PDCCH monitoring occasion for PUSCH preparation time is the latter PDCCH monitoring occasion.Proposal 3: For “the first DCI format” associated to mTRP PDCCH repetition, * + - The PDCCH monitoring occasion, where the UE detects the first DCI format scheduling an initial transmission of a transport block since a PHR was triggered, for determining whether a PHR for a serving cell is based on actual transmission or reference format is
			* Alt-1: the latter PDCCH monitoring occasion of the PDCCH candidates associated to the first DCI format.
			* Alt-2: the earlier PDCCH monitoring occasion of the PDCCH candidates associated to the first DCI format.

Proposal 4: For UE supporting more than one CC, * + - Two search space sets for linking PDCCH candidate repetition are configured in a same CC.
 |

# **Reference**

[1] R1-2106464 Enhancements on multi-TRP for reliability and robustness in Rel-17 Huawei, HiSilicon

[2] R1-2106542 Multi-TRP enhancements for PDCCH, PUCCH and PUSCH ZTE

[3] R1-2106572 Further discussion on Multi-TRP for PDCCH, PUCCH and PUSCH enhancements vivo

[4] R1-2106641 Discussion on Enhancements for PDCCH, PUCCH, and PUSCH InterDigital, Inc.

[5] R1-2106667 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Lenovo, Motorola Mobility

[6] R1-2106686 Discussion on enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Spreadtrum Communications

[7] R1-2106790 Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH Sony

[8] R1-2106866 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Samsung

[9] R1-2106936 Enhancements on multi-TRP/panel transmission for PDCCH, PUCCH and PUSCH CATT

[10] R1-2107030 Enhancements on Multi-TRP for PDCCH PUCCH and PUSCH Fujitsu

[11] R1-2107079 Multi-TRP/panel for non-PDSCH FUTUREWEI

[12] R1-2107144 Discussion on multi-TRP for PDCCH, PUCCH and PUSCH NEC

[13] R1-2107204 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH OPPO

[14] R1-2107293 Discussion on enhancements on multi-TRP for uplink channels FGI, Asia Pacific Telecom

[15] R1-2107324 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Qualcomm Incorporated

[16] R1-2107391 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH CMCC

[17] R1-2107465 On multi-TRP enhancements for PDCCH and PUSCH Fraunhofer IIS, Fraunhofer HHI

[18] R1-2107486 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH MediaTek Inc.

[19] R1-2107571 Multi-TRP enhancements for PDCCH, PUCCH and PUSCH Intel Corporation

[20] R1-2107719 Views on Rel-17 multi-TRP reliability enhancement Apple

[21] R1-2107815 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH LG Electronics

[22] R1-2107839 Discussion on MTRP for reliability NTT DOCOMO, INC.

[23] R1-2107894 Enhancements on Multi-TRP for PDCCH, PUSCH and PUCCH Xiaomi

[24] R1-2108020 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH Convida Wireless

[25] R1-2108053 Enhancements for Multi-TRP URLLC schemes Nokia, Nokia Shanghai Bell

[26] R1-2108072 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH TCL Communication Ltd.

[27] R1-2108074 On PDCCH, PUCCH and PUSCH enhancements for multi-TRP Ericsson

[28] R1-2108106 Discussion on mTRP PXXCH ASUSTeK

# **Appendix: Previous Agreements**

**RAN1 #104-b-e:**

**Agreement**

When DL DCI is transmitted via PDCCH repetition, for PUCCH resource determination for HARQ-Ack when the corresponding PUCCH resource set has a size larger than eight, starting CCE index and number of CCEs in the CORESET of one of the linked PDCCH candidates is applied, and option 2 is supported

* Option 2: The one with the lowest SS set ID is applied.
* FFS: Support of Option 2 does not mean PDCCH repetition based on two linked search space set within one CORESET is supported

**Agreement**

For PDSCH rate matching around the scheduling DCI in the case of PDCCH repetition, the previous agreement for FR1 also applies to FR2.

**Agreement**

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

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

**Agreement**

If a PDSCH with mapping Type B is scheduled by a DCI in PDCCH candidates that are linked for repetition

* For the purpose of the earliest time that the PDSCH can be scheduled as well as for the purpose of the reference symbol for SLIV (when UE is configured with *ReferenceofSLIV-ForDCIFormat1\_2*, and when receiving the PDSCH scheduled by DCI format 1\_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with K0=0), a reference candidate is used. Select one among the following:
	+ Alt1: The candidate that starts later in time
	+ Alt3: The candidate that starts earlier in time
* FFS: How to define *d1,1* $d\_{1,1}$for PDSCH processing time in this case

**Agreement**

If a PDSCH is scheduled by a DCI in PDCCH candidates (the first PDCCH candidate associated with a first CORESET and the second PDCCH candidate associated with a second CORESET) that are linked for repetition,

* **Working assumption**: The UE expects the same configuration for the first and second CORESETs wrt presence of TCI field in DCI.
* If the TCI field is not present in the DCI, and the scheduling offset is equal to or larger than timeDurationForQCL if applicable, PDSCH QCL assumption is based on the CORESET with lower ID among the first and second CORESETs
* FFS: Whether additional options are needed (e.g. to enable SDM/FDM/TDM PDSCH schemes w/o TCI field in the DCI)

**Agreement**

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

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

**Agreement**

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

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

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

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

**Agreement**

For PDCCH repetition with two linked candidates, if due to Rel. 15/16 procedures, one of the linked candidates is not monitored (is dropped), select one option from Options 1 and 2 in RAN1#105-e:

* Option 1: UE still monitors the linked candidate that is not dropped and interprets the DCI based on Rel. 17 PDCCH rules (wrt reference PDCCH candidate)
* Option 2: Even the candidate that is not dropped is not monitored (Both linked candidates are dropped if at least one of them is dropped)
* FFS: Which of the following Rel. 15/16 rules are applicable for this purpose:
	+ Case 1: Overlap with SSB
	+ Case 2: Overlap with rate matching resources: RateMatchPattern, lte-CRS-ToMatchAround, or LTE-CRS-PatternList-r16, availableRB-SetPerCell-r16
	+ Case 3: Due to TDD DL/UL related conflicts: Overlap with semi-static / dynamic UL symbols or overlap with PRACH
	+ Case 4: QCL-TypeD prioritization rule among CORESETs result in one of the linked candidates not being monitored
	+ Case 5: Overbooking results in one of the linked candidates not being monitored
	+ Case 6: Overlap with reserved PRB(s) and OFDM symbol(s) indicated by DCI format 2\_1 where UE may assume no transmission intended for the UE
	+ Other cases are not precluded
* FFS: Whether there is an impact to BD count

**RAN1 #104-e:**

**Agreement**

Confirm the working assumption:

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

**Agreement**

When DL DCI is transmitted via PDCCH repetition, for PUCCH resource determination for HARQ-Ack when the corresponding PUCCH resource set has a size larger than eight, starting CCE index and number of CCEs in the CORESET of one of the linked PDCCH candidates is applied. Down-select one of the following options in RAN1 #104-bis-e

* Option 1: The one with the lowest CORESET ID is applied
* Option 2: The one with the lowest SS set ID is applied.

**Agreement**

For Option 2, at least for the following purposes, a reference PDCCH candidate is defined as the candidate that ends later in time among the two linked PDCCH candidates in the time domain:

* To determine the scheduling offset to identify whether a default beam should be used for PDSCH / CSI-RS reception.
* To extend the definition of in-order for PDCCH-PDSCH and PDCCH-PUSCH, i.e., PDCCH ending symbol is the last symbol of the reference PDCCH candidate in at least the following restrictions in 38.214.
	+ 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 ending in symbol I, the UE is not expected to be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH that ends later than symbol i.
	+ 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 ending in symbol I, the UE is not expected to be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH that ends later than symbol i.
* For PUSCH preparation time (N2) and CSI computation time (Z): Last symbol of the PDCCH is based on the last symbol of the reference PDCCH candidate.
* FFS: If inter-slot PDCCH repetition is supported, for slot offset for scheduling the same PDSCH/PUSCH/CSI-RS/SRS: The slot of the reference PDCCH candidate is used as the reference slot.

**Agreement**

If two PDCCH candidates that are linked for repetition do not belong to the same PDCCH monitoring occasion, the earlier PDCCH monitoring occasion is used as the reference for the following:

* Definition of counter DAI / total DAI and Type-2 HARQ-Ack codebook construction.
* Determining the last DCI for PUCCH resource determination based on the PRI field of the last DCI.

**Agreement**

Study whether / how to resolve the following potential issues in the case of PDCCH repetition:

* Issue 1: Starting symbol for PDSCH mapping type B as well as reference symbol for SLIV (i.e., when ReferenceofSLIV-ForDCIFormat1\_2 is configured).
* Issue 2: Determination of PDSCH beam when TCI field is not present in DCI (when scheduling offset is equal to or larger than timeDurationForQCL)
* Issue 3: When PDCCH repetitions are associated with different CORESETPoolIndex values, and the need to use one of them as reference for PDSCH scrambling / CRS rate matching / HARQ-Ack / etc.
	+ Whether PDCCH repetition can be used with multi-DCI based multi-TRP.
* Issue 4: Whether single-TRP PDCCH repetition is supported by reusing the agreed framework.

**Agreement**

For PDCCH repetition, support linking two SS sets by RRC configuration:

* FFS: Whether MAC-CE can be used additionally
* When PDCCH repetition is monitored in two linked SS sets, the UE does not expect a third monitored SS set to be linked with any of the two linked SS sets.
* The two linked SS sets have the same SS set type (USS/CSS)
	+ The two linked SS sets have the same DCI formats to monitor
* For intra-slot PDCCH repetition,
	+ The two SS sets should have the same periodicity and offset (monitoringSlotPeriodicityAndOffset), and the same duration
	+ For linking monitoring occasions across the two SS sets that exist in the same slot:
		- The two SS sets have the same number of monitoring occasions within a slot and n-th monitoring occasion of one SS set is linked to n-th monitoring occasion of the other SS set

**Agreement**

For number of BDs corresponding to two PDCCH candidates that are linked for PDCCH repetition, down-select one of the following options in RAN1 #104-bis-e

* Option 1: UE reports one or more numbers as required number of BDs for the two PDCCH candidates
	+ Candidate values: 2, X.
		- Where X is a value larger than 2 and equal or less than 3
		- FFS: Whether a value between 1 and 2 should be added to the candidate values
		- FFS: Other values
* Option 2: UE reports whether it supports soft-combining or not
	+ If soft-combining is supported, UE further reports one or more numbers as required number of BDs for the two PDCCH candidates
		- Candidate values: 2, X.
			* Where X is a value larger than 2 and equal or less than 3
			* FFS: Whether a value between 1 and 2 should be added to the candidate values
			* FFS: Other values
* Option 3: UE reports one or more decoding assumptions out of decoding assumptions 1-4
	+ Number of BDs for decoding assumptions 1:
		- Alt1: 2 BDs
		- Alt2: A value between 1 and 2 BDs
	+ Number of BDs for decoding assumption 2: 2
	+ Number of BDs for decoding assumption 3: 2
		- FFS: Other values
	+ Number of BDs for decoding assumption 4: 3
		- FFS: Other values
* Option 4: Always 2 BDs are assumed irrespective of UE’s decoding assumption
* Option 5: Always 3 BDs are assumed irrespective of UE’s decoding assumption
* FFS: Network configuration based on the above UE capabilities for options 1-3

Note: Specification should not be designed in such a way that the UE is required to disclose it receiver implementation

**Agreement**

At least for FR1, if a PDSCH is scheduled by a DCI in PDCCH candidates that are linked for repetition, and the resources in the CORESET(s) containing the PDCCH candidates overlap with the resources of the PDSCH, the PDSCH is rate matched around the union of two PDCCH candidates and the corresponding DMRS.

* Note: This does not imply that two linked PDCCH candidates can / cannot be overlapping in resources, which is a separate discussion.
* FFS: The case of FR2

**Agreement**

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

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

**Agreement**

For PDCCH repetition, two PDCCH candidates in two SS sets are linked based on

* Having the same AL and the same candidate index:
	+ Two linked SS sets are configured with the same number of candidates for each AL.

**Conclusion.**

The agreed PDCCH repetition framework (Option 2 + Case 1 + Alt3) supports both TDM and FDM multiplexing schemes.

**RAN1 #103-e:**

**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

**Working Assumption**

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

**Agreement**

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 combinedcandidate
* 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 on the configuration of PDCCH monitoring capability (e.g. per slot or per span).

**Conclusion**

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

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

**Agreement**

When DL DCI is transmitted via PDCCH repetition (Option2 + Case 1), for PUCCH resource determination for HARQ-Ack when the corresponding PUCCH resource set has a size larger than eight:

* Alt 1: Ensure same start CCE index (based on linking options) and the same number of CCEs in the two CORESETs (based on CORESET configuration restriction)
* Alt 2: Starting CCE index and number of CCEs in the CORESET of one of the linked PDCCH candidates is applied
	+ FFS:  Which one of the linked PDCCH candidates is used.
* Alt 3: It is up to the UE to determine the PUCCH resource based on the starting CCE index and number of CCEs in the CORESET of any of the two linked PDCCH candidates
* Other alternatives are not precluded.

**RAN1 #102-e:**

**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 PDCCHOption 2: Spec transparent SFNFor FR1: Both options 1 and 2 can be consideredFor 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