3GPP TSG RAN WG1 #107-e R1-2xxxxxx

e-Meeting, November 11th – 19th, 2021

**Agenda item: 8.1.2.1**

**Source:** **Moderator (Nokia, Nokia Shanghai Bell)**

**Title: Summary #1 of Multi-TRP PUCCH and PUSCH Enhancements**

**Document for: Discussion and Decision**

# Introduction

The Rel-17 work item for enhancements on MIMO for NR includes an objective to extend specification support for enhancements on multi-TRP/panel transmission. In RAN #86, the objectives were agreed to read as follows:

*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*

In this document, proposals on the reliability and robustness improvements for PUCCH and PUSCH are summarized in section 2 and 3. The agreements reached in previous RAN1 meetings are provided in Section 5.

# Multi-TRP PUCCH transmission

The remaining open issues and company views are summarized below.

## 2.1 Issue #1: UCI multiplexing

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| *Company proposals*   1. *Consider enhancements on UCI multiplexing for multi-TRP based PUCCH repetition in Rel-17. – [2]* 2. *Confirm that Rel-15/16 collision handling between PUCCH repetition and other channels/signals are also applicable for Rel-17 M-TRP PUCCH repetition schemes. – [5], [28]* 3. *When mTRP PUCCH needs to be dropped due to collision handling rule, only the PUCCH repetition in the overlapped symbols should be dropped. – [19]* |

FL views that there is no time in Rel-17 to do any enhancements on collision handling considering mTRP PUCCH transmission. The following proposal was considered in RAN1 #106bis but it was not endorsed due to one company concern. Let’s try the same proposal again to close any future discussions on this.

***Proposed conclusion 2.1:*** *Rel-15/16 collision handling between PUCCH repetition and other channels/signals are also applicable for Rel-17 M-TRP PUCCH repetition schemes.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
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## 2.2 Issue #2: Default assumptions on mTRP PUCCH repetitions.

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| *Company proposals*   1. *Support up to two default beams and two default power control parameter sets for PUCCH in multiple TRPs. – [4]* 2. *A new RRC parameter is introduced to enable two default beams and PL-RSs for PUCCH, and if it is configured SFN and non-SFN CORESET for the lowest CORESET ID – [6]* 3. *If the UE is not provided pathlossReferenceRSs, define how to enable the UE to determine two RS resources needed to calculate two pathloss values for PUCCH power control - [23]* |

To FL reading, mTRP PUCCH schemes are applied when the MAC-CE provides two spatial relation info or two power control sets. And it is not fully clear in which scenario that mTRP PUCCH schemes can be active when such MAC-CE is not received (seems to be the assumption in ([4] and [23]). Proponents may further justify the criticalness of their proposals for mTRP PUCCH repetition schemes. Also, the proposal on new RRC (in [6]) may not be valid for this AI as it is about SFN and non-SFN CORESETs. No FL proposal.

Please comment if further discussions are needed on above company proposals.

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| **Company** | **Comments** |
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## 2.3 Issue #3: Switching of mTRP PUCCH schemes

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| *Company proposals*   * *Support dynamic switching between the multi-TRP PUCCH schemes. – [23]*   + *If configuring two PUCCH configurations at a time is supported, reuse PHY priority, or introduce something similar to PHY priority, to indicate which PUCCH configuration and thus which multi-TRP PUCCH scheme to use at a given time.*   + *If a single PUCCH configuration is kept/supported, allow association between PUCCH resources and multi-TRP PUCCH schemes, to allow the indication of which multi-TRP PUCCH scheme to use at a given time through the indicated PUCCH resource* |

Dynamic switching between PUCCH inter-slot and intra-slot may be feasible if two PUCCH configurations are configured with different priority levels by using PHY priority (regardless sTRP or mTRP transmission). However, when these schemes are having same PHY priority, there is no dynamic switching supported even for sTRP inter-slot and intra-slot PUCCH repetition modes. May be further inputs from companies would be good to conclude this.

***Question 2.3:*** *Please indicate the views on supporting dynamic switching between the multi-TRP PUCCH schemes (Scheme 1 vs Scheme 3).*

Please add your views.

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| **Company** | **Comments** |
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## 2.4 Additional high priority proposals

If you wish to bring any additional aspects related to PUCCH during RAN1 #107-e, please comment below.

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| **Company** | **Comments** |
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# Multi-TRP PUSCH transmission

The remaining open issues and company views are summarized below.

## 3.1 Issue #1: Minimal gap between associated NZP-CSI-RS and AP NCB SRS

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| **Agreement**  For NCB based mTRP PUSCH repetition, on the minimal gap between associated NZP-CSI-RS and aperiodic NCB SRS, select one from the below in RAN1 #107-e meeting,   * Alt. 1: If both SRS resource sets are triggered in an overlapped manner in time domain (overlapping refer to overlapping of minimal gaps between two pairs of associated NZP-CSI-RS and aperiodic SRS corresponding to two SRS resource sets), the UE is not expected to update the SRS precoding information if the gap from the last symbol of the reception of the aperiodic NZP-CSI-RS resource and the first symbol of the aperiodic SRS transmission is less than 42 + d OFDM symbols, where d indicates the number of overlapped symbols for the two pairs of associated NZP-CSI-RS and aperiodic SRS for NCB.   + FFS: value of d * Alt. 2: UE is not expected to support overlapping precoding calculation for different associated NZP-CSI-RS within a CC, i.e., the UE is not expected to get triggering for two SRS resource sets in an overlapped manner in time domain (overlapping refer to overlapping of minimal gaps between two pairs of associated NZP-CSI-RS and aperiodic SRS corresponding to two SRS resource sets).   + The minimal gap between associated NZP-CSI-RS and aperiodic SRS is same as Rel-15/16. * Alt.3: Introduce a UE capability on UE support simultaneous precoding calculation for different associated NZP-CSI-RS within a CC.   + The minimal gap between associated NZP-CSI-RS and aperiodic SRS is same as Rel-15/16. * Alt. 4: There is nothing wrong with the legacy procedures and capability indication to handle this issue. No changes to spec.   *Company views*   * *Alt.1 – Spreadtrum, OPPO (2nd), NEC, Apple, E///* * *Alt.2 – HW, LG* * *Alt.3 – FW, LG, Intel, Nokia, QC (UE FG AI), TCL, MTek* * *Alt.4 – ZTE, vivo, CATT, OPPO (1st), Xiaomi, CMCC, DCM, Nokia, MTek* |

From FL view, Alt.3 and Alt.4 having a better support compared to other alternatives. Among Alt.3 and 4, Alt.4 has a slight majority. As this seems not critical to discuss in this AI, we can conclude this issue as below (a combination of Alt.3 and Alt. 4).

***Proposed conclusion 3.1:*** *For NCB based mTRP PUSCH repetition, no changes to the Rel-15/16 defined minimal gap between associated NZP-CSI-RS and aperiodic SRS.*

* *Note: Whether to introduce a UE capability on UE support simultaneous precoding calculation for different associated NZP-CSI-RS within a CC can be further discussed in UE capability discussions.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
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## 3.2 Issue #2: PT-RS DMRS association

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| *Company views*   1. *Define an association between PT-RS-DMRS association indicated by MSB or LSB and a PUSCH transmission occasion according to the 1st SRS resource set or according to the 2nd SRS resource set. – [4]* 2. *Only the first PTRS-DMRS association field is used when STRP is indicated. – [6]* |

From FL view, issues highlighted by [4] and [6] are already handled in the endorsed draft CR for 38.212.

Please comment any other critical changes related to PT-RS DMRS association.

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| **Company** | **Comments** |
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## 3.3 Issue #3: CG PUSCH

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| *Company views*   1. *When DCI format 0\_1 or DCI format 0\_2 that does not include the new 2-bits DCI field for dynamic switching activates a type 2 CG or schedules retransmission of a type1 or type 2 CG, and the CG configuration is configured with two sets of power control parameters, the first set of power control parameters associated with the first SRS resource set is applied. – [6]* 2. *For a BWP configured with two SRS resource sets for CB or NCB based mTRP PUSCH repetition with Type 1 CG configuration, if the CG is configured with two fields for each of ‘pathlossReferenceIndex’, 'srs-ResourceIndicator', 'precodingAndNumberOfLayers', 'p0-PUSCH-Alpha' and 'powerControlLoopToUse', the first and second fields are associated with the first and second SRS resource sets, respectively. – [28]* 3. *For mTRP type 1 CG PUSCH, when two fields of 'precodingAndNumberOfLayers' and/or 'srs-ResourceIndicator' are present in 'rrc-ConfiguredUplinkGrant', the same number of layers should be indicated in the first and second fields.- [28]* 4. *Introduce a new field for dynamic switching in a type 1 CG configuration when two power control parameter fields are configured in the CG configuration. – [4]* |

From FL reading,

* the first proposal is not a valid scenario as SRS resource set indicator field should be present when the UE configured with two SRS resource sets.
* the second proposal is already captured in the CRs 38.213 and 38.214.
* third proposal should be general understanding but may be worth agreeing explicitly.
* fourth proposal was considered before in RAN1 discussion (with no agreement).

***Proposed conclusion 3.3:*** *For mTRP type 1 CG PUSCH, when two fields of 'precodingAndNumberOfLayers' and/or 'srs-ResourceIndicator' are present in 'rrc-ConfiguredUplinkGrant', the same number of layers should be indicated in the first and second fields.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
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## 3.4 Issue #4: SRS resources

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| *Company views*   1. *The value of the NSRS,0\_2 in two SRS resource sets configured by higher layer parameter srs-ResourceSetToAddModListDCI-0-2 should be the same –* ***ZTE, Spreadtrum, CATT, OPPO, Intel, Xiaomi, FGI*** 2. *For codebook based mTRP PUSCH, the UE capability on 'fullyAndPartialAndNonCoherent', 'partialAndNonCoherent', or 'nonCoherent' is applicable to PUSCH transmissions associated to both SRS resource sets. – [28]* 3. *Discuss cases when only one/two SRS resource set is configured in srs-ResourceSetToAddModList and two/one SRS resource sets are configured in srs-ResourceSetToAddModListDCI-0-2 – [6], [10]* |

From FL reading,

* good support on first proposal from multiple companies and a valid discussion point.
* second proposal does need explicit agreement in this AI. Also, based on the UE capability of mTRP PUSCH and the UE capability of CB based PUSCH transmission type (from Rel-15/16 capability), the network can distinguish the supported mTRP PUSCH operation(s). This can be further discussed, if needed, in UE feature AI.
* third proposal seems not needed as Spec drafts covering it already.

***Proposal 3.4:*** *For mTRP PUSCH repetition scheduled with DCI format 0\_2, the value of the in two SRS resource sets configured by higher layer parameter srs-ResourceSetToAddModListDCI-0-2 should be the same.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
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## 3.5 Issue #5: SRI to PUSCH power control mappings

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| *Company views*   * *For non-codebook based mTRP PUSCH scheduled by a DCI, the SRI indicated in the 2nd SRI field is used to determine a new SRI in a corresponding legacy SRI table for the indicated SRS resources and number of layers. The new SRI is then used to determine a set of PUSCH power control parameters based the SRI to PUSCH power control mappings configured for the 2nd SRS resource set. – [28]* |

As 1st SRI field also used to interpret the SRI carried in the 2nd SRI field for NCB based mTRP PUSCH repetition, it seems that the above proposal in E/// contribution is valid, and FL suggest discussing it further.

***Proposal 3.5:*** *For non-CB based mTRP PUSCH repetition, the SRI indicated in the 2nd SRI field is used to determine a new SRI in a corresponding legacy SRI table for the indicated SRS resources and number of layers. The new SRI is then used to determine a set of PUSCH power control parameters based the SRI to PUSCH power control mappings configured for the 2nd SRS resource set.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
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## 3.6 Issue #6: PHR Triggering/Reporting

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| *Company views*   1. *Discuss triggering procedures to measure pathloss/power factor changes per PL-RS, and other related aspects – [1], [22]* 2. *For multi-TRP PHR reporting, the first PHR and the second PHR corresponds to the ordering of the TRPs (SRS resource sets) based on the DCI codepoint. – [14]* 3. *Introduce new RRC parameter to indicate per-TRP PHR for UE that reports this UE optional capability – [18]* 4. *Discuss details for a cell with two carriers (i.e., non-SUL, SUL carrier) that each carrier is configured with mTRP PUSCH repetition or PUCCH repetition – [25]* |

From FL view,

* + First proposal was tried in the last RAN1 meeting, and there was no agreement.
  + Second proposal seems not aligned with the earlier RAN1 agreement as we referred to slot n to derive the first PHR value.
  + Third proposal on new RRC seems redundant and nothing critical.
  + Fourth proposal is talking about SUL and non-SUL carrier PHR reporting. Some further inputs on this may be needed to decide the validity of this issue.

Please comment any critical changes to PHR reporting from above company proposals 1-4 (specially based on the fourth proposal above from ASUSTeK).

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| **Company** | **Comments** |
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## 3.7 Issue #7: Multiplexing aspects

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| *Company views*   1. *When PUCCH without repetition carrying HARQ-ACK and/or CSI overlaps with multi-TRP PUSCH transmission, the UCI of the PUCCH is multiplexed on two PUSCH repetitions with different beams – [2]* 2. *When A-CSI or SP-CSI is multiplexed on two mTRP PUSCH repetitions without data, and the mTRP PUCCH repetitions overlap with the PUSCH repetitions, and the overlapped PUCCH and PUSCH is targeted to the same TRP (which is ensured by gNB implementation), multiplex the UCI on both PUSCH repetitions and drop the PUCCH repetitions. – [14]* 3. *When mTRP PUSCH collides with PUCCH, support that UCI can be transmitted in the first actual PUSCH repetition corresponding to each beam based on the A-CSI report operation in mTRP PUSCH. – [19]* 4. *Discuss overlapping PUCCHs/PUSCHs for multi-TRP operation – [21]* |

From FL view, above company proposals are not critical to finalize Rel-17 WI and can be considered as further optimizations. No further discussion is encouraged on this.

Please comment if further discussions are needed on above company proposals.

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| **Company** | **Comments** |
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## 3.8 Issue #8: Power control parameter sets

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| *Company views*   1. When twoPUSCH-PC-AdjustmentStates is configured and one SRS resource per SRS resource set is configured (i.e., when two SRI fields are absent in DCI formats 0\_1 / 0\_2), if the first P0-PUSCH-AlphaSet in P0-AlphaSet is reconfigured, closed-loop adjustment state with index l = 0 should be reset; if the PC parameters in the second P0-PUSCH-AlphaSet in P0-AlphaSet is reconfigured, closed-loop adjustment state with index l = 1 should be reset. – [11] 2. *When twoPUSCH-PC-AdjustmentStates is configured and DCI schedules a retransmission of CG-PUSCH for type 1 CG or type 2 CG (DCI with CRC scrambled with CS-RNTI and NDI=1) while the CG configuration is RRC-configured with two fields of power control parameters , if the first (legacy) RRC-configured fields ‘p0-PUSCH-Alpha’ is reconfigured, closed-loop adjustment state with the first (legacy) ‘powerControlLoopToUse’ should be reset; if the second (new) RRC-configured fields ‘p0-PUSCH-Alpha’ is reconfigured, closed-loop adjustment state with the second (new) ‘powerControlLoopToUse’ should be reset. – [11]* |

From FL view, the proposals in [11] require further inputs.

***Question 3.8:*** *Please indicate the views on the following proposals.*

* When twoPUSCH-PC-AdjustmentStates is configured and one SRS resource per SRS resource set is configured (i.e., when two SRI fields are absent in DCI formats 0\_1 / 0\_2), if the first P0-PUSCH-AlphaSet in P0-AlphaSet is reconfigured, closed-loop adjustment state with index l = 0 should be reset; if the PC parameters in the second P0-PUSCH-AlphaSet in P0-AlphaSet is reconfigured, closed-loop adjustment state with index l = 1 should be reset.
* When twoPUSCH-PC-AdjustmentStates is configured and DCI schedules a retransmission of CG-PUSCH for type 1 CG or type 2 CG (DCI with CRC scrambled with CS-RNTI and NDI=1) while the CG configuration is RRC-configured with two fields of power control parameters , if the first (legacy) RRC-configured fields ‘p0-PUSCH-Alpha’ is reconfigured, closed-loop adjustment state with the first (legacy) ‘powerControlLoopToUse’ should be reset; if the second (new) RRC-configured fields ‘p0-PUSCH-Alpha’ is reconfigured, closed-loop adjustment state with the second (new) ‘powerControlLoopToUse’ should be reset.

Please add your views.

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| **Company** | **Comments** |
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## 3.9 Issue #9: Other issues

Some company proposals from contributions (not listing proposals discussed in past with no outcome) are listed below. Please indicate which proposals deemed essential for further discussion. Please find moderator understanding under each item (in blue text).

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| *Company views*   1. *For BWP switching between two BWPs with different number of SRS resource sets, - [6]*  * *When DCI indicates BWP switch from a BWP with MTRP configuration to a BWP with STRP configuration and schedules a PUSCH, UE ignores the new field and the second SRI/TPMI/TPC fields in the DCI;* * *When DCI indicates BWP switch from a BWP with STRP configuration to a BWP with MTRP configuration and schedules a PUSCH, UE assumes the only SRI/TPMI/TPC field in the DCI are associated to the first SRS resource set in the indicated BWP.*   ***Mod: DCI fields can be interpreted based on associated configurations after BWP switch. There seems nothing critically wrong.***   1. *For non-codebook based M-TRP PUSCH repetition transmission, two sets of SRI-PUSCH-PowerControl are configured, and an additional offset determined by the number of layers can be introduced when UE obtains a mapping from sri-PUSCH-PowerControlId in SRI-PUSCH-PowerControl between a set of values for the second SRI field, which is given by, i.e., the actually mapped sri-PUSCH-PowerControlId is equal to the value of the second SRI field plus the offset. – [6]*   ***Mod: Mapping of SRI to PUSCH-PowerControl is considered under section 3.5.***   1. *Whether two values of CORESETPoolIndex can be configured together with two configured SRS resource sets for PUSCH or two activated spatial relations for a PUCCH resource. – [6]*   ***Mod: CORESETPoolIndex configuration seems not impacting PUSCH repetition configurations. Nothing critically wrong here.***   1. *When the legacy table (7.2.1.1.2-25 or 7.2.1.1.2-26 in TS 38.212) shall be determined based on the legacy procedure, the interpretation of codepoints in the table should be different from the interpretation of codepoints in the legacy table according to TRP, the max number of UL PTRS ports (maxNrofPorts) and the number of actual PTRS ports. Therefore, in order to prevent possible misunderstandings, define new tables for PTRS-DMRS association field with Rel-17 multi-TRP PUSCH repetition. – [18]*   ***Mod: this issue was solved in the last meeting. FL do not see a need of discussing it again to define new tables.***     1. *With regard to cross-slot channel estimation, support to configure the number of consecutive slots per beam for sequential mapping, where the candidate value is based on the candidate time domain bundling window size for cross-slot channel estimation. – [19]*   ***Mod: there is no further time in Rel-17 mTRP UL to discuss channel estimation enhancements***   1. *When TB over multiple slots is enabled, the beam mapping pattern, i.e. cyclic mapping and sequential mapping, should be defined in repetition level. – [19]*   ***Mod: Rel-17 mTRP PUSCH only support repetition Type A and B, no support defined for TBoMS.***   1. *Support configuring invalid symbol pattern per TRP for multi-TRP operation. – [21]*   ***Mod: nothing critical to finalize Rel-17***   1. *Introduce a RRC parameter to enable/disable the new behaviour of transmitting AP/SP-CSI on two PUSCH repetitions with different beams. The new parameter can be per CSI-AperiodicTriggerState or CSI-SemiPersistentOnPUSCH-TriggerState. – [24]*   ***Mod: seems ok to introduce a new RRC such that legacy vs Rel-17 operations can be controlled by the network node.***   1. *A second SRS request field can be added in the DCI and the first and second SRS request fields are used to trigger the first and second aperiodic SRS resource sets toward the first and second TRPs respectively. – [26]*   ***Mod: not essential optimization at this stage.*** |

Please add your views.

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| **Company** | **Comments** |
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Based on FL analysis above, only following is considered as FL proposal.

***Proposal 3.9:*** *For mTRP PUSCH repetition, introduce a RRC parameter to enable/disable the new behaviour of transmitting AP/SP-CSI on two PUSCH repetitions with different beams. The new parameter can be per CSI-AperiodicTriggerState or CSI-SemiPersistentOnPUSCH-TriggerState.*

Please add your views.

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| **Company** | **Comments** |
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## 3.10 Additional high priority proposals

If you wish to bring any additional aspects related to PUCCH during RAN1 #107, please comment below.

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| **Company** | **Comments** |
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# Reference

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| 1. **[R1-2110762](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110762.zip)** | Further Discussion on Enhancements for PDCCH, PUCCH, and PUSCH | InterDigital, Inc. |
| 1. [**R1-2110782**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110782.zip) | Enhancements on multi-TRP for reliability and robustness in Rel-17 | Huawei, HiSilicon |
| 1. [**R1-2110879**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110879.zip) | Multi-TRP/panel for non-PDSCH | FUTUREWEI |
| 1. [**R1-2110933**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110933.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Lenovo, Motorola Mobility |
| 1. [**R1-2110949**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110949.zip) | Multi-TRP enhancements for PDCCH, PUCCH and PUSCH | ZTE |
| 1. [**R1-2110991**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110991.zip) | Remaining issues on Multi-TRP for PDCCH, PUCCH and PUSCH enhancements | vivo |
| 1. [**R1-2111085**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111085.zip) | Discussion on enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Spreadtrum Communications |
| 1. [**R1-2111144**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111144.zip) | Enhancements on Multi-TRP for PDCCH PUCCH and PUSCH | Fujitsu |
| 1. [**R1-2111170**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111170.zip) | On multi-TRP enhancements for PDCCH | Fraunhofer IIS, Fraunhofer HHI |
| 1. [**R1-2111222**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111222.zip) | Remaining issues on multi-TRP/panel for PDCCH, PUCCH and PUSCH | CATT |
| 1. [**R1-2111280**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111280.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | OPPO |
| 1. [**R1-2111381**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111381.zip) | Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH | Sony |
| 1. [**R1-2111454**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111454.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | LG Electronics |
| 1. [**R1-2111477**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111477.zip) | Multi-TRP enhancements for PDCCH, PUCCH and PUSCH | Intel Corporation |
| 1. [**R1-2111541**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111541.zip) | Enhancements on Multi-TRP for PDCCH, PUSCH and PUCCH | Xiaomi |
| 1. [**R1-2111598**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111598.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | CMCC |
| 1. [**R1-2111684**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111684.zip) | Discussion on multi-TRP for PDCCH, PUCCH and PUSCH | NEC |
| 1. [**R1-2111718**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111718.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Samsung |
| 1. [**R1-2111854**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111854.zip) | Views on Rel-17 multi-TRP reliability enhancement | Apple |
| 1. [**R1-2112026**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112026.zip) | Multi-TRP Enhancements for PDCCH | Convida Wireless |
| 1. [**R1-2112074**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112074.zip) | Discussion on enhancements on multi-TRP for uplink channels | FGI, Asia Pacific Telecom |
| 1. [**R1-2112090**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112090.zip) | Discussion on MTRP for reliability | NTT DOCOMO, INC. |
| 1. [**R1-2112177**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112177.zip) | Enhancements for Multi-TRP URLLC schemes | Nokia, Nokia Shanghai Bell |
| 1. [**R1-2112197**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112197.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Qualcomm Incorporated |
| 1. [**R1-2112269**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112269.zip) | Discussion on mTRP PUSCH | ASUSTeK |
| 1. [**R1-2112271**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112271.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | TCL Communication Ltd. |
| 1. [**R1-2112277**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112277.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | MediaTek Inc. |
| 1. [**R1-2112320**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112320.zip) | Remaining issues on PDCCH, PUSCH and PUCCH enhancements for multi-TRP | Ericsson |

# Previous Agreements

## 5.1 PUCCH Agreements

### 102-e (August 2020)

**Agreement**

* Detailed assumptions for PUCCH evaluation:

|  |  |
| --- | --- |
| Parameters | Potential values |
| Baseline scheme | Rel-15 PUCCH repetition |
| PUCCH format | Format 1 and 3.  Other PUCCH Formats can be optionally considered. |
| # of RBs/symbols | PUCCH Format 1: 4 symbols, 1 RB  PUCCH Format 3: 4 and 8 symbols, 1 RB  Other combinations are not precluded. |
| UCI payload | 2 bits for PUCCH Format 1 (and Format 0, if considered).  Companies to report assumptions on other PUCCH Formats |
| Frequency hopping | Reported by companies |
| Number of repetitions (when applicable) | 2, 4, 8 |
| Schemes | TDM  Details to be reported by companies |
| Receiver assumption | Reported by companies |

* Detailed assumptions for PUSCH evaluation:

|  |  |
| --- | --- |
| Parameters | Potential values |
| Baseline scheme | Rel-15/-16 PUSCH repetition |
| # of RBs/symbols | Companies to Report. |
| DMRS pattern | DM-RS configuration type 1  DM-RS Configuration type 2 (optional) |
| # of layers | 1, 2 (optional) |
| Code rates | Low (<0.2) and moderate (<0.4) |
| Frequency hopping | Reported by companies |
| UL transmission scheme | Codebook based UL transmission is baseline. Non-codebook based can be optional. |
| Redundancy Version | Reported by companies |
| Number of repetitions (when applicable) | 2, 4, 8  Other numbers are not precluded |
| Schemes | TDM  Details to be reported by companies |
| Receiver assumption | Reported by companies |

**Agreement**

To improve reliability and robustness for PUCCH using multi-TRP and/or multi-panel, consider all PUCCH formats.

**Agreement**

To enable TDMed PUCCH transmission with different beams, support configuring/activating of multiple PUCCH Spatial Relation Info. RAN1 shall further study the exact schemes considering the following aspects,

* Method of configuration/activation of multiple spatial relation info
* Use of the same PUCCH resource or different PUCCH resource for PUCCH transmission
* Mapping between PUCCH repetition/symbol and spatial relation info among multiple PUCCH repetitions / multiple PUCCH symbols.

**Agreement**

For configuration/indication of the number of PUCCH repetitions, RAN1 shall further study the following,

* Alt.1: Use Rel-15 like framework
* Alt.2: Dynamic indication of the number of PUCCH repetitions

**Agreement**

For multi-TRP PUCCH transmission, further investigate required power control enhancement.

**Agreement**

Support TDMed PUCCH scheme(s) to improve reliability and robustness for PUCCH using multi-TRP and/or multi-panel. Study the following alternatives,

* Alt.1: supporting both inter-slot repetition and intra-slot repetition / intra-slot beam hopping.
* Alt.2: supporting only inter-slot repetition
* Note1: It is not precluded to study the use of multiple PUCCH resources to repeat the same UCI in both inter-slot repetition and intra-slot repetition.
* Note2: The alternatives are clarified as below,
  + inter-slot repetition: One PUCCH resource carries UCI , another one or more PUCCH resources or the same PUCCH resource in another one or more slots carries a repetition of the UCI .
  + intra-slot repetition: One PUCCH resource carries UCI , another one or more PUCCH resources or the same PUCCH resource in another one or more sub-slots carries a repetition of the UCI
  + intra-slot beam hopping: UCI is transmitted in one PUCCH resource in which different sets of symbols have different beams

### 103-e (November 2020)

**Agreement**

For multi-TRP PUCCH transmission schemes.

* Support multi-TRP inter-slot repetition (Scheme 1)
  + One PUCCH resource carries UCI, another PUCCH resource or the same PUCCH resource in another one or more slots carries a repetition of the UCI.
  + FFS: Number of repetitions
* Further study the support (one or both) of the following schemes
  + Multi-TRP intra-slot beam hopping (Scheme 2)
    - UCI is transmitted in one PUCCH resource in which different sets of symbols within the PUCCH resource have different beams.
    - FFS: More than 2 beam hopping instances per PUCCH resource.
  + Multi-TRP intra-slot repetition (Scheme 3)
    - One PUCCH resource carries UCI, another PUCCH resource or the same PUCCH resource in another one or more sub-slots within a slot carries a repetition of the UCI.
* Note1: whether to support two PUCCH resources or the same PUCCH resource with different beams for Scheme 1 and 3 to be discussed separately.

**Agreement**

For multi-TRP PUCCH transmission schemes,

* For Scheme 1, at least PUCCH format 1/3/4 can be used.
* FFS: Support of PUCCH format 0/2 for Scheme 1
* FFS: Support of PUCCH formats for Scheme 2 and/or Scheme 3 (if schemes are agreed).

**Agreement**

For multi-TRP TDM-ed PUCCH transmission schemes,

* Support the use of a single PUCCH resource
* Up to two spatial relation info’s can be activated per PUCCH resource via MAC CE
* FFS: Required enhancements for FR1
* FFS: Use of multiple PUCCH resources.

**Agreement**

For PUCCH multi-TRP enhancements in FR2,

* Support separate power control parameters for different TRP via associating power control parameters via PUCCH spatial relation info.
  + Note: No spec impact.
* For per TRP closed-loop power control for PUCCH, further study the following alternatives considering TPC command when the “closedLoopIndex” values associated with the two PUCCH spatial relation info’s are not the same.
  + Option.1: A single TPC field is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for both PUCCH beams
  + Option.2: A single TPC field is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for one of two PUCCH beams at a slot. The TPC value may be applied for the other PUCCH beam at an another slot.
  + Option 3: A second TPC field is added in DCI formats 1\_1 / 1\_2.
  + Option 4: A single TPC field is used in DCI formats 1\_1 / 1\_2, and indicates two TPC values applied to two PUCCH beams, respectively.
* FFS: Transition period for beam / power / frequency change.
* FFS: Required power control enhancements for FR1

**Agreement**

For configuration/indication of the number of PUCCH repetitions for Scheme 1, there is no restriction on using Rel-15 framework on configuring the number of repetitions.

* Rel-17 feMIMO may additionally consider supporting the dynamic indication of the number of repetitions in RAN1 #104 meeting.

**Agreement**

For PUCCH multi-TRP enhancements in FR1,

* Support separate power control for different TRP.
* FFS: how to define the association between PUCCH and TRP.
* FFS: required enhancements.

**Working Assumption**

For PUCCH multi-TRP enhancements in Scheme 1, it is possible to configure either cyclic mapping or sequential mapping of spatial relation info’s over PUCCH repetitions.

* FFS: Applicability of mapping patterns for different beam switching gaps
* The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.
* Note: For Scheme 1, cyclical mapping pattern and sequential mapping pattern are as follows,
  + Cyclical mapping pattern: the first and second beam are applied to the first and second PUCCH repetition, respectively, and the same beam mapping pattern continues to the remaining PUCCH repetitions.
  + Sequential mapping pattern: the first beam is applied to the first and second PUCCH repetitions, and the second beam is applied to the third and fourth PUCCH repetitions, and the same beam mapping pattern continues to the remaining PUCCH repetitions.

**Agreement**

LS to RAN4 on beam switching gaps for multi-TRP UL transmission is endorsed in R1-2009807.

### 104-e (February 2021)

**Agreement**

For M-TRP PUCCH scheme 1,

* Support PUCCH formats 0 and 2 (in addition to agreed PUCCH formats 1,3,4)

**Agreement**

For M-TRP PUCCH scheme 1,

* For PUCCH formats 1/3/4, values for the total number of repetitions at least contain values 2, 4, and 8.
  + FFS: maximum repetition number can be extended to 16.
* For PUCCH formats 0/2, the total number of repetitions at least contain 2.
  + FFS: other values.
* RRC configured number of slots (repetitions) are applied across both TRPs (e.g if the number of repetitions given by *nrofSlots* in *PUCCH-config* is 8, per TRP limit is 4).

**Agreement**

To support per TRP power control for multi-TRP PUCCH schemes in FR1,

* Two sets of power control parameters are used, and each set has a dedicated value of p0, pathloss RS ID and a closed-loop index.
* FFS: details on how a PUCCH resource can be linked to one or both of the two sets of power control parameters.
* FFS: whether PUCCH resource group can be linked to power control parameter sets.

**Working Assumption**

For PUCCH reliability enhancement, support multi-TRP intra-slot repetition (Scheme 3) for all PUCCH formats.

1. The same PUCCH resource carrying UCI is repeated for X = 2 [consecutive] sub-slots within a slot.
2. Refer the design details related to sub-slot configurations (e.g. other values of X) to Rel-17 eIIoT

Note1: The decision of supporting scheme 3 is only applicable for multi-TRP operation.

**Conclusion**

For Multi-TRP PUCCH Scheme 1/3 at least containing HARQ ACK, supporting dynamic switching between multi-TRP PUCCH scheme and single-TRP PUCCH transmission is not restricted, and can be done by associating,

* a PUCCH resource activated with one or two spatial-relation-info and PRI bit-field indicating a PUCCH resource,
* or a PUCCH resource with one or two power control parameter sets and PRI bit-field indicating a PUCCH resource

FFS: Support of dynamic switching for Scheme 2 (if the schemes supported)

**Conclusion**

Strive to reuse the specification support for dynamic indication of number of repetitions introduced in the Rel-17 coverage enhancement work item for multi-TRP operation. Decide whether further enhancements for multi-TRP operation are necessary in RAN1#106bis. No further discussion on this topic until RAN1#106bis under agenda item 8.1.

**Agreement**

Further study following aspects related to beam mapping and default behaviors for multi-TRP PUCCH/PUSCH schemes,

* Whether enhancements needed on beam mapping in case of PUCCH/PUSCH dropping due to invalid UL symbols
* Whether frequency hopping is performed among the repetitions with the same beam
* Whether defining default beam for PUSCH is needed when PUSCH scheduled by DCI format 0\_0 when two spatial relation info’s are configured for a PUCCH resource

**Agreement**

Further study following alternatives to support per TRP closed-loop power control for PUCCH , select  from the below options during the RAN1 #104-e-bis meeting.

* Option.1: A single TPC field (the existing TPC field) is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for both PUCCH beams
* Option.2: A single TPC field (the existing TPC field) is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for one of two PUCCH beams at a slot. The TPC value may be applied for the other PUCCH beam at an another slot.
* Option 3: A second TPC field (similar to the existing TPC field) is added in DCI formats 1\_1 / 1\_2.
* Option 4: A single TPC field is used in DCI formats 1\_1 / 1\_2, and indicates two TPC values applied to two PUCCH beams, respectively.

**Working assumption**

For beam mapping /power control parameter set mapping for PUCCH repetitions,

* For M-TRP PUCCH Scheme 1 in FR1, it is possible to configure either cyclic mapping or sequential mapping of power control parameter sets over PUCCH repetitions (similar to spatial relation info’s over PUCCH repetitions).
* For M-TRP PUCCH Scheme 3, reuse the same methods as Scheme 1 (by replacing slots with sub-slots) for beam mapping or power control resource set mapping to sub-slots.
* This working assumption is also subjected to the RAN4 LS R1-2009807 and confirmed based on the RAN4 reply.

### 104-bis-e (April 2021)

**Agreement**

For the case of multi-TRP, to support per-TRP power control in FR1, the linking of PUCCH resource with [one or] two power control parameter sets, the following is supported

* MAC-CE indicates RRC IE that configures power control parameter sets (p0, pathloss RS ID, and a closed-loop index).
  + The exact design of RRC IE is up to RAN2 but from RAN1 point of view, one possible example is to reuse *PUCCH-SpatialRelationInfo* except for the *referenceSignal*

Note: It is common understanding in RAN1 that one PUCCH resource can be linked to one power control parameter set.

**Conclusion**

With reference to the normative work on NR-feMIMO:

Related to the support of switching gap between UL transmissions towards two TRPs in RAN1 specifications, there is no consensus in RAN1 to specify symbol gap(s) for the following cases

* PUSCH Type A
* PUCCH scheme 1
* PUSCH Type B
* PUCCH scheme 3

The above applies for the case included in the LS from RAN4 in R1-2102297.

**Agreement**

When inter-slot frequency hopping is configured with Scheme 1, decide one from the below options in RAN1#105-e meeting,

* Option 1
  + If sequential mapping pattern is configured, frequency hopping is performed on slot level (as in Rel-15).
  + If cyclical mapping pattern is configured, frequency hopping is performed among the repetitions with the same beam.
* Option 2:
  + gNB always configures sequential mapping pattern and frequency hopping is performed on slot level. (no spec impact)
* Option 3:
  + Frequency hopping is performed on slot level as in Rel-15 (no spec impact).

**Agreement**

**Confirm the following Working Assumption**:

For PUCCH multi-TRP enhancements in Scheme 1, it is possible to configure either cyclic mapping or sequential mapping of spatial relation info’s over PUCCH repetitions.

* FFS: Applicability of mapping patterns for different beam switching gaps
* The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.
* Note: For Scheme 1, cyclical mapping pattern and sequential mapping pattern are as follows,
  + Cyclical mapping pattern: the first and second beam are applied to the first and second PUCCH repetition, respectively, and the same beam mapping pattern continues to the remaining PUCCH repetitions.
  + Sequential mapping pattern: the first beam is applied to the first and second PUCCH repetitions, and the second beam is applied to the third and fourth PUCCH repetitions, and the same beam mapping pattern continues to the remaining PUCCH repetitions.

**Agreement**

**Confirm the following Working Assumption** (with small correction of typo and clarification on UE capability in RED):

* For beam mapping /power control parameter set mapping for PUCCH repetitions,
  + For M-TRP PUCCH Scheme 1 in FR1, it is possible to configure either cyclic mapping or sequential mapping of power control parameter sets over PUCCH repetitions (similar to spatial relation info’s over PUCCH repetitions).
  + For M-TRP PUCCH Scheme 3, reuse the same methods as Scheme 1 (by replacing slots with sub-slots) for beam mapping or power control ~~resource~~ parameter set mapping ~~to sub-slots~~.
  + The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.

### 105-e (May 2021)

**Agreement**

For multi-TRP PUCCH (scheme 1 and 3) and PUSCH (Type A and B) repetition, when the number of repetitions is equal to two, the first and second transmission occasion shall be associated with two TRPs, respectively (two UL beams or Power control parameter sets), regardless of the configured mapping pattern.

* Note: For M-TRP PUSCH type B, the number of repetitions refers to ‘nominal’ repetition.

**Agreement**

Confirm the working assumption with removing brackets on [consecutive] and adding UE capability.

* For PUCCH reliability enhancement, support multi-TRP intra-slot repetition (Scheme 3) for all PUCCH formats.
  + The same PUCCH resource carrying UCI is repeated for X = 2 ~~[~~consecutive~~]~~ sub-slots within a slot.
  + Refer the design details related to sub-slot configurations (e.g. other values of X) to Rel-17 eIIoT
* Note1: The decision of supporting scheme 3 is only applicable for multi-TRP operation.
* This feature is optional.

**Conclusion**

For multi-TRP PUCCH schemes, only one ‘twoPUCCH-PC-AdjustmentStates’ parameter is configured for both TRPs, and the parameter is shared across both TRPs, which means there will be two closed loops in total (no RAN1 spec impact).

**For future meetings:**

Further study the enhancements needed on grouping of PUCCH resources for Rel-17 multi-TRP PUCCH repetition

**Agreement**

* To support per TRP closed-loop power control for PUCCH with DCI formats 1\_1 / 1\_2, a second TPC field can be configured via RRC.
* When the second field is configured by RRC, a second TPC field (similar to the existing TPC field) is added in DCI formats 1\_1 / 1\_2 (option 3).
  + Each TPC field is for each closed-loop index value respectively
    - FFS: Whether or not the mapping between the TPC field and the PUCCH transmissions is needed
* When the second field is not configured by RRC, a single TPC field (the existing TPC field) is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for the closed loop index(es) for the scheduled PUCCH
* To support per TRP closed-loop power control for PUSCH with DCI formats 0\_1 / 0\_2, adopt the same solution as with M-TRP PUCCH schemes.
  + FFS: any additional considerations
* Support UE to report the capability on whether it supports the second TPC field
* Note1: Per TRP closed-loop power control is only applicable when the “closedLoopIndex” values are not the same for TRPs.

### 106-e (August 2021)

**Agreement**

For per-TRP closed-loop power control, when the indicated PUCCH transmission in DCI format 1\_0 (fallback DCI) is associated with two “*closedLoopIndex*” values for multi-TRP PUCCH transmission schemes, the single TPC field (the existing TPC field) is applied to both closed loop indices for the scheduled PUCCH.

**Agreement**

For the grouping of PUCCH resources in Rel-17 multi-TRP PUCCH repetition schemes,

* Support MAC-CE activating two spatial relation info’s (for FR2) for a group of PUCCH resources in a CC.
* Support MAC-CE activating two sets of power control parameters (for FR1) for a group of PUCCH resources in a CC.
* When the PUCCH resource is indicated with two spatial relation info’s or two sets of power control parameters (via a MAC-CE that activating two spatial relation info’s or a MAC-CE that activating two sets of power control parameters for a group of PUCCH resources, respectively), the other PUCCH resources in the group also get updated to have the same two spatial relation info’s or two sets of power control parameters.
* When the PUCCH resource is indicated with one spatial relation info or one set of power control parameters (via a MAC-CE that activating single spatial relation info or a MAC-CE that activating single set of power control parameters for a group of PUCCH resources, respectively), then the other PUCCH resources in the group also get updated to have the same spatial relation info or the same set of power control parameters.
* The signalling details are up to RAN2 to decide.
* Note: Impacts coming from coverage enhancement work item on associating PUCCH resource with repetition factor can be discussed separately

**Agreement**

For per-TRP closed-loop power control,

* When the second TPC field is configured and the indicated PUCCH transmission in DCI formats 1\_1/1\_2  (or PUSCH transmission in DCI formats 0\_1/0\_2) is associated with one “*closedLoopIndex*” value for single TRP transmission, the other TPC field associated with the other “*closedLoopIndex*” value is unused.
* Note1: Each TPC field is for each closed-loop index value respectively (i.e., 1st /2nd TPC fields correspond to “*closedLoopIndex*” value = 0 and 1, respectively).
* Note2: When the other TPC field associated with the other “*closedLoopIndex*” value is unused, the unused TPC field is not applied for any legacy procedures of calculating sum of TPC command values.

**Agreement**

For mTRP PUCCH (or PUSCH) repetitions schemes,

* When the second TPC field is configured and the indicated PUCCH transmission in DCI formats 1\_1/1\_2 (or PUSCH transmission in DCI formats 0\_1/0\_2) is associated with the same “*closedLoopIndex*” value for mutli-TRP tranmission, the other TPC field associated with the other “*closedLoopIndex*” value is unused.
* Note: When the other TPC field associated with the other “*closedLoopIndex*” value is unused, the unused TPC field is not applied for any legacy procedures of calculating sum of TPC command values.

**Agreement**

If the PUCCH resource with the lowest ID is activated with two spatial relation info, the spatial relation info with lower ID, is used as the default beam for PUSCH scheduled by DCI format 0\_0.

**Conclusion**

There is no consensus in RAN1 to support inter-slot PDCCH repetition in Rel. 17.

## 5.2 PUSCH Agreements

### 102-e (August 2020)

**Agreement**

For M-TRP PUSCH reliability enhancement, support single DCI based PUSCH transmission/repetition scheme(s).

* Further study multi-DCI based PUSCH transmission/repetition scheme(s) to identify potential gains and required enhancements.
* Note: This agreement does not reflect any prioritization of single DCI based PUSCH transmission/repetition over multi-DCI based PUSCH transmission/repetition. Ran1 can further discuss that in the next meeting.

**Agreement**

For single DCI based M-TRP PUSCH reliability enhancement, support TDMed PUSCH repetition scheme(s) based on Rel-16 PUSCH repetition Type A and Type B.

* Further study PUSCH transmission without repetition as a potential candidate M-TRP PUSCH scheme

**Agreement**

To support single DCI based M-TRP PUSCH repetition scheme(s), up to two beams are supported. RAN1 shall further study the details considering,

1. Codebook based and non-codebook based PUSCH
2. Enhancements on SRI/TPMI/power control parameters/any other

Note1: Companies are encouraged to provide additional details on how above enhancements are applied to different PUSCH repetitions (e.g. mapping between PUSCH repetitions and beams)

Note2: Studying enhancements/aspects related to TA is not precluded.

**Agreement**

Further study M-TRP CG PUSCH reliability enhancements in Rel-17.

**Agreement**

On the mapping between PUSCH repetitions and beams in single DCI based multi-TRP PUSCH repetition Type A and Type B, further study the following,

* For both PUSCH repetition Type A and B, how the beams are mapped to different PUSCH repetitions (or slots/frequency hops),
  + Alt.1: cyclical mapping pattern (the first and second beam are applied to the first and second PUSCH repetition, respectively, and the same beam mapping pattern continues to the remaining PUSCH repetitions).
  + Alt.2: sequential mapping pattern (the first beam is applied to the first and second PUSCH repetitions, and the second beam is applied to the third and fourth PUSCH repetitions, and the same beam mapping pattern continues to the remaining PUSCH repetitions).
  + Alt.3: Half-Half pattern (the first beam is applied to the first half of PUSCH repetitions, and the second beam is applied to the second half of PUSCH repetitions)
  + Alt.~~3~~4: Other variants (e.g. configurable mapping patterns)
  + Note1: For PUSCH repetition type B, the variants considering slot level beam mapping with the same mapping principals (replacing repetition with slot) in Alt.1/2/3 are also included.
  + Note2: For PUSCH repetition type A and B with frequency hopping, the variants considering frequency hop level beam mapping with the same mapping principals (replacing repetition with frequency hop) in Alt.1/2/3 can also be studied further. Final selection of such schemes also depends on the number of beams allowed per PUSCH repetition.
* For PUSCH repetition Type B, which repetition type that the beams shall consider for the mapping,
  + Alt.1: beams are mapped to the nominal repetitions
  + Alt.2: beams are mapped to the actual repetitions
  + Alt.3: beams are mapped to different slots (not in the granularity of actual/nominal repetition)
  + Alt.4: Other variants
* Consider additional requirements on switching gap(s) between two PUSCH repetitions towards different TRPs considering beam switching latency aspects.
* Note: use of the above solutions to multi-DCI based PUSCH repetition and TDMed PUSCH transmission without repetition (when there are agreed to support) is not precluded.

### 103-e (November 2020)

**Agreement**

For single DCI based M-TRP PUSCH repetition schemes, support codebook based PUSCH transmission with following enhancements.

* Support the indication of two SRIs.
  + Alt1: Bit field of SRI shall be enhanced.
  + Alt2: No changes on SRI field
* Support the indication of two TPMIs.
  + The same number of layers are applied for both TPMIs if two TPMIs are indicated
  + The number of SRS ports between two TRPs should be same.
  + FFS: Details on indicating two TPMIs (e.g, one TPMI field or two TPMI fields)
* Increase the maximum number of SRS resource sets to two
* FFS: configuration details of each SRS resource set (e.g., number of SRS resources in a resource set)

**Agreement**

For single DCI based M-TRP PUSCH repetition schemes, support non-codebook based PUSCH transmission with following considerations.

* Increase the maximum number of SRS resource sets to two, and associated CSI-RS resource can be configured per SRS resource set.
* FFS: Enhancements on SRI field in DCI to indicate the two beams for repetitions

**Agreement**

For single DCI based M-TRP PUSCH repetition Type B, at least nominal repetitions are used to map beams

* Further study details and applicability of each mapping method
* Further study the slot based beam mapping in the cases of nominal repetition across slot boundaries

**Agreement**

For PUSCH multi-TRP enhancements,

* For per TRP closed-loop power control for PUSCH, further study the following alternatives when the “closedLoopIndex” values are different.
  + Option.1: A single TPC field is used in DCI formats 0\_1 / 0\_2, and the TPC value applied for both PUSCH beams
  + Option.2: A single TPC field is used in DCI formats 0\_1 / 0\_2, and the TPC value applied for one of two PUSCH beams at a slot.
  + Option 3: A second TPC field is added in DCI formats 0\_1 / 0\_2.
  + Option 4: A single TPC field is used in DCI formats 0\_1 / 0\_2, and indicates two TPC values applied to two PUSCH beams, respectively.
* FFS: Transition period for beam / power / frequency change.

**Agreement**

Support both type 1 and type 2 CG PUSCH transmission towards MTRP. Further study the following alternatives,

* Alt.1 : single CG configuration
  + Repetitions of a TB transmitted towards MTPR on multiple PUSCH transmission occasions of single CG configuration.
  + At least for codebook-based CG PUSCH, support configuring 2 SRIs/TPMIs.
* Alt.2 : multiple CG configurations
  + Repetitions of a TB transmitted towards MTRP on more than one PUSCH transmission occasions, where one or more transmission occasions are from one CG configuration and another one or more PUSCH transmission occasions are from another CG configuration.
  + 1 SRI/TPMI is configured/indicated for each CG configuration.
* Further study required beam mapping principals, low overhead mechanisms for beam selection, and other enhancements for Alt.1 and Alt.2.

**Agreement**

For M-TRP PUSCH reliability enhancement, further discuss multi-DCI based PUSCH transmission/repetition scheme(s) considering the following aspects.

* The same TB is repeated towards multiple TRPs with different beams, where one or more PUSCH repetitions are scheduled by one DCI and another one or more PUSCH repetitions are scheduled by another DCI.
* FFS: Details related to timeline restrictions and beam mapping
* Changes on Rel-15/16 MCS, TBS determination, and UL resource allocation are not expected from this scheme.
* The scheme is considered to be supported only if there are gains over single DCI based PUSCH repetition schemes and a similar scheme is not supported by m-TRP PDCCH (e.g. Option 3).

Companies are encouraged to provide simulation results to decide the support of the scheme in next RAN1 meetings

The support of multi-DCI based PUSCH transmission/repetition scheme(s) in Rel-17 will be decided in RAN1#104-e

**Agreement**

For single DCI based PUSCH multi-TRP enhancements, support the following RV mapping for PUSCH repetition Type A,

* DCI indicates the first RV for the first PUSCH repetition, and the RV pattern (0 2 3 1) is applied separately to PUSCH repetitions of different TRPs with a possibility of configuring RV offset for the starting RV for the second TRP (The same method as PDSCH scheme 4)
* FFS: Reuse of the same method for PUSCH repetition Type B.

**Agreement**

For single DCI based M-TRP PUSCH repetition Type A and B, further study required enhancements on PTRS-DMRS association.

**Working Assumption**

For single DCI based M-TRP PUSCH repetition Type A and B, it is possible to configure either cyclic mapping or sequential mapping of UL beams.

* The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.
* FFS: Support of half-half mapping.
* FFS: Additional considerations on mapping patterns (including required beam switching gaps)
* Companies are encouraged to provide further simulation results to decide details.

**Agreement**

LS to RAN4 on beam switching gaps for multi-TRP UL transmission is endorsed in R1-2009807.

### 104-e (February 2021)

**Agreement**

For single DCI based M-TRP PUSCH repetition Type B, support the following RV mapping,

* DCI indicates the first RV for the first PUSCH actual repetition, and the RV pattern (0 2 3 1) is applied separately to PUSCH actual repetitions of different TRPs with a possibility of configuring RV offset for the starting RV for the first actual repetition towards second TRP (The same method as PDSCH scheme 4).

**Agreement**

Support CG PUSCH transmission towards M-TRPs using a single CG configuration.

* Use same beam mapping principals as dynamic grant PUSCH repetition scheme.
* FFS: Required changes on CG parameters (ConfiguredGrantConfig)
* The feature is UE optional

**Agreement**

For single-DCI based M-TRP PUSCH repetition schemes, up to two power control parameter sets (using *SRI-PUSCH-PowerControl*) can be applied when SRS resources from two SRS resource sets indicated in DCI format 0\_1/0\_2.

* FFS1: Details on linking SRI fields to two power control parameters,
  + Alt. 1: Add second *sri-PUSCH-MappingToAddModList*, and select two *SRI-PUSCH-PowerControl* from two *sri-PUSCH-MappingToAddModList*
  + Alt. 2: Add SRS resource set ID in *SRI-PUSCH-PowerControl*, and select *SRI-PUSCH-PowerControl* from *sri-PUSCH-MappingToAddModList* considering the SRS resource set ID
  + Alt. 3: Let RAN2 handle this
  + Alt.4: Add second *sri-PUSCH-PathlossReferenceRS-Id*/*sri-P0-PUSCH-AlphaSetId*/*sri-PUSCH-ClosedLoopIndex* in *SRI-PUSCH-PowerControl*.
* FFS2: Enhancements on open-loop power control parameter set indication
* FFS3: Consideration on *srs-PowerControlAdjustmentStates*
* FFS4: Impact of multi-TRP PUSCH repetition on PHR reporting
* FFS5: Enhancement on power control parameters per TRP when SRI(s) indication of two SRS resource sets is absent.

**Agreement**

For single DCI based M-TRP PUSCH repetition schemes, in codebook based PUSCH,

* Support two SRI fields corresponding to two SRS resource sets are included in DCI formats 0\_1/0\_2.
  + Each SRI field indicating SRI per TRP, where the SRI field based on Rel-15/16 framework
* Support dynamic switching between multi-TRP and single-TRP operation
* FFS: Support dynamic switching the order of two TRPs

**Agreement**

For single DCI based M-TRP PUSCH Type B repetition schemes,

* For maxRank = 2, the number of bits for the indication of PTRS-DMRS association is the same as Rel-15/16, MSB and LSB separately indicating the association between PTRS port and DMRS port for two TRPs.
* FFS: the indication of PTRS-DMRS association for maxRank > 2.

**Agreement**

For s-DCI based multi-TRP PUSCH repetition Type A and B, if the DCI schedules A-CSI, support multiplexing A-CSI on the first PUSCH repetition corresponding to the first beam and the X-th PUSCH repetition corresponding to the second beam.

* For PUSCH repetition Type A, X=1 (the first PUSCH repetition corresponding to the second beam)
* For PUSCH repetition Type B, the first actual PUSCH repetition corresponding to the first beam and the X-th actual repetition corresponding to the second beam are considered,
  + The UE does not expect the first actual repetition corresponding to the first beam and the X-th actual repetition corresponding to the second beam to have a single symbol duration (similar restriction as in Rel-16 NR for the single TRP case).
  + The first actual repetition corresponding to the first beam and the X-th actual repetition corresponding to the second beam are expected to have the same number of symbols
  + FFS: X = 1 or X = the first actual repetition corresponding to the second beam that contains the same number of symbols as the first actual repetition with the first beam
* FFS: Any further restrictions/enhancements needed on supporting A-CSI multiplexing on PUSCH repetitions
* FFS: whether to support multiplexing SP-CSI/P-CSI on PUSCH repetitions towards multiple TRPs.

**Agreement**

Further study following aspects related to beam mapping and default behaviors for multi-TRP PUCCH/PUSCH schemes,

* Whether enhancements needed on beam mapping in case of PUCCH/PUSCH dropping due to invalid UL symbols
* Whether frequency hopping is performed among the repetitions with the same beam
* Whether defining default beam for PUSCH is needed when PUSCH scheduled by DCI format 0\_0 when two spatial relation info’s are configured for a PUCCH resource

**Agreement**

For single DCI based M-TRP PUSCH repetition schemes, in codebook based PUSCH,

* Two TPMI fields are indicated in DCI formats 0\_1/0\_2.
  + The first TPMI field uses the Rel-15/16 TPMI field design (which includes TPMI index and the number of layers) of DCI format 0\_1/0\_2. The second TPMI field only contains~~indicates~~ the second TPMI index. The same number of layers are applied as indicated in the first TPMI field.
  + FFS: Details of second TPMI field interpretation including changes expected in Tables 7.3.1.1.2-2/2A/2B/3/3A/4/4A/5/5A in 38.212
  + FFS: Interpreting TPMI fields when multi-TRP and single-TRP PUSCH repetition is applied.
* FFS: whether to support of PUSCH repetitions transmitting towards two TRPs sharing the same TPMI indicated by a TPMI field.
* FFS: The size of the second TPMI field can be equal to or smaller than the size of the first TPMI field

**Agreement**

For single DCI based M-TRP PUSCH repetition schemes, in non-codebook based PUSCH,

* Support two SRI field(s) corresponding to two SRS resource sets are included in DCI formats 0\_1/0\_2.
  + Each SRI field indicating SRI per TRP, where the first SRI field based on Rel-15/16 framework,
  + Support the same number of layers applied over repetitions
  + FFS: details of second SRI field including the specification change for Table 7.3.1.1.2-28/29/30/31 in 38.212.
* Support dynamic switching between multi-TRP and single-TRP operation
  + FFS: whether/how to use SRI field(s) and additional details of SRI field(s) interpretations
* FFS: Minimizing the DCI overhead for PUSCH repetition Type A as a result of number of layers being limited to 1 when more than one repetition is scheduled.
* FFS: Support dynamic switching the order of two TRPs
* Companies are encouraged to provide total payload size of the two SRI fields and scheduling restriction, if any

**Agreement**

Further study following alternatives to support per TRP closed-loop power control for PUSCH , select from the below options during the RAN1 #104-e-bis meeting.

* Option.1: A single TPC field (the existing TPC field) is used in DCI formats 0\_1 / 0\_2, and the TPC value applied for both PUSCH beams
* Option.2: A single TPC field (the existing TPC field) is used in DCI formats 0\_1 / 0\_2, and the TPC value applied for one of two PUSCH beams at a slot.
* Option 3: A second TPC field (similar to the existing TPC field) is added in DCI formats 0\_1 / 0\_2.
* Option 4: A single TPC field is used in DCI formats 0\_1 / 0\_2, and indicates two TPC values applied to two PUSCH beams, respectively.

### 104-bis-e (April 2021)

**Agreement**

When SRS resources from two SRS resource sets indicated in DCI format 0\_1/0\_2, for linking SRI fields to two power control parameters, it is up to RAN2 to finalize the RRC details related to linking. RAN1 identified that the following options could be used.

* Alt. 1: Add second *sri-PUSCH-MappingToAddModList*, and select two *SRI-PUSCH-PowerControl* from two *sri-PUSCH-MappingToAddModList*
* Alt. 2: Add SRS resource set ID in *SRI-PUSCH-PowerControl*, and select *SRI-PUSCH-PowerControl* from *sri-PUSCH-MappingToAddModList* considering the SRS resource set ID

**Agreement**

For PHR reporting related to M-TRP PUSCH repetition, select one from the following options in RAN1 #105-e meeting.

* Option 1:  Calculate one PHR associated with the first PUSCH occasion (earliest repetition that overlaps with the first slot in which the PUSCH that carries the PHR MAC-CE is transmitted)
* Option 2: Calculate two PHRs, each associated with a first PUSCH occasion to each TRP, but report one of them
  + FFS: How to select the PHR for reporting.
* Option 4: Calculate two PHRs, each associated with a first PUSCH occasion to each TRP, and report two PHRs
* Option 5: No changes to legacy PHR reporting

**Agreement**

When MAC-CE indicates a PL-RS ID for one or more SRI IDs, it also indicates whether the SRI IDs are associated with the first or the second SRS resource set.

**Agreement**

For multiplexing A-CSI on two PUSCH repetitions in the case of multi-TRP PUSCH repetition,

* For S-DCI based multi-TRP PUSCH repetition Type B, support multiplexing A-CSI on the first PUSCH repetition corresponding to the first beam and the first (X = 1) PUSCH repetition corresponding to the second beam.
  + The UE is expected to follow the above operation for multiplexing A-CSI on two PUSCH repetitions only if
    - the first actual repetition corresponding to the first beam and the first actual repetition corresponding to the second beam have the same number of symbols, and
    - UCIs other than the A-CSI are not multiplexed on any of the two PUSCH repetitions.
  + When the UE does not follow the above operation, UE multiplexes A-CSI only on the first PUSCH repetition similar to Rel. 15/16.
* The content for the two A-CSI should be the same
* Note: RAN1 has the assumption on CSI timelines are followed as rel-15/16, including UE shall expect the timeline for the first A-CSI meets Z and Z’ requirement
* FFS: For s-DCI based multi-TRP PUSCH repetition Type A and B, support multiplexing of A-CSI on the first PUSCH repetition corresponding to the first beam and the first PUSCH repetition corresponding to the second beam when there is no TB carried in the PUSCH.
  + The UE assumes that the number of repetitions is 2 regardless of the indicated number of repetitions.
  + For PUSCH repetition Type B, the first and second nominal repetitions are expected to be the same as the first and second actual repetitions, respectively (no segmentation).

**Working Assumption**

For indicating STRP/MTRP dynamic switching for non-CB/CB based MTRP PUSCH repetition,

* Introduce a new field in DCI to indicate at least the S-TRP or M-TRP operation
  + FFS: Whether the new field is 1 bit or 2 bits

**Working Assumption**

For non-codebook based multi-TRP PUSCH, the first SRI field is used to determine the entry of the second SRI field which only contains the SRI(s) combinations corresponding to the indicated rank (number of layers) of the first SRI field. The number of bits, *N2*, for the second SRI field is determined by the maximum number of codepoint(s) per rank among all ranks associated with the first SRI field. For each rank x, the first *Kx* codepoint(s) are mapped to *Kx* SRIs of rank x associated with the first SRS field, the remaining (2N2-*Kx*) codepoint(s) are reserved.



**Agreement**

For the indication of open-loop power control parameter (OLPC) in DCI format 0\_1/0\_2, support enhanced open-loop power control parameter (OLPC) set indication by indicating per-TRP OLPC set.

* FFS: Details of indication.

**Agreement**

For CB based M-TRP PUSCH repetition, the first TPMI field is used to determine the entry of the second TPMI field which only contains TPMIs corresponding to the indicated rank (number of layers) of the first TPMI field. The second TPMI field’s bit width, *M2*, is determined by the maximum number of TPMIs per rank among all ranks associated with the first TPMI field. For each rank y, the first *Ky* codepoint(s) of the second TPMI field are mapped to *Ky* TPMI(s) of rank y associated with the first TPMI field in increasing order codepoint index, the remaining (2M2-*Ky*) codepoint(s) are reserved.



* How to describe/capture this in 38.212 is up to the editor.

**Agreement**

**Confirm the following working assumption** (with removing the last bullet):

For single DCI based M-TRP PUSCH repetition Type A and B, it is possible to configure either cyclic mapping or sequential mapping of UL beams.

* The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.
* FFS: Support of half-half mapping.
* FFS: Additional considerations on mapping patterns (including required beam switching gaps)

**Agreement**

For single DCI based M-TRP PUSCH Type B repetition, the indication of PTRS-DMRS association for maxRank > 2 is supported, down select one of the following options in RAN1 #105-e meeting,

* The support of cyclic mapping can be optional UE feature for the cases when the number of repetitions is larger than 2.
* Option 1 (4 bits): with a second PTRS-DMRS association field (similar to the existing field), and each field separately indicating the association between PTRS port and DMRS port for two TRPs.
* Option 2 (2 bits): using the existing PTRS-DMRS association field in DCI for the first TRP, and using reserved entries/bits in DM-RS port indication field for the second TRP.
* Option 3 (2 bits): 1 bit MSB is used to indicate PTRS-DMRS association for the first TRP, and 1 bit LSB is used to indicate PTRS-DMRS association for the second TRP
  + if *maxNrofPorts* = 1, the 1 bit indicates one of the first two DMRS ports.
  + if *maxNrofPorts* = 2, the 1 bit indicates one of two DMRS ports sharing the same PTRS port.

**Agreement**

For type 1 or type 2 CG based multi-TRP PUSCH repetition,

* Introduce the second fields of *'p0-PUSCH-Alpha*' and '*powerControlLoopToUse*' in '*ConfiguredGrantConfig*’
* For type 1 CG based m-TRP PUSCH repetition, introduce the second fields of ‘*pathlossReferenceIndex*’, *'srs-ResourceIndicator*' and '*precodingAndNumberOfLayers*' in *'rrc-ConfiguredUplinkGrant*'.
* For type 2 CG based M-TRP PUSCH, two SRIs/TPMIs are indicated via the activating DCI.
* FFS1: UL PT-RS port(s) and DM-RS port(s) for CG type 1
* FFS3: Details on RV mapping.
* FFS4: Possible transmission occasion for initial transmission
* FFS5: Other TRP specific parameters in '*rrc-ConfiguredUplinkGrant*', e.g., *'dmrs-SeqInitialization*'.

### 105-e (May 2021)

**Agreement**

For indicating per-TRP OLPC set in DCI format 0\_1/0\_2, if two SRI fields present in the DCI,

* Use the existing field (1 bit) for OLPC set indication and a second p0-PUSCH-SetList-r16.
  + if value of the field equals to ‘0’, the UE determine value of P0 from*SRI-PUSCH-PowerControl* with a sri-*PUSCH-PowerControlId* value mapped to the SRI field value corresponding to each TRP.
  + if value of the field equals to ‘1’, the UE determine value of P0 from a first value in P0-PUSCH-Set with a p0-PUSCH-SetId value mapped to the SRI field value corresponding to each TRP.

**Agreement**

For s-DCI based multi-TRP PUSCH repetition Type A and B, support transmitting A-CSI on the first PUSCH repetition corresponding to the first beam and the first PUSCH repetition corresponding to the second beam when there is no TB carried in the PUSCH.

* The UE assumes that the number of repetitions is 2 regardless of the indicated number of repetitions.
* The UE is expected to follow the above operation for transmitting A-CSI on two PUSCH repetitions only if
  + For PUSCH repetition Type B, the first and second nominal repetitions are expected to be the same as the first and second actual repetitions, respectively (no segmentation).
  + For PUSCH repetition Type A and B, UCIs other than the A-CSI are not multiplexed on any of the two PUSCH repetitions.
* When the UE does not follow the above operation, UE transmits A-CSI only on the first PUSCH repetition similar to Rel. 15/16.
* Note: The scheduling offset for the first A-CSI should meet the Z and Z’ requirement

**Agreement**

For s-DCI based multi-TRP PUSCH repetition Type A, the UE is expected to multiplex A-CSI on two PUSCH repetitions only if UCIs other than the A-CSI are not multiplexed on any of the two PUSCH repetitions.

* When the UE does not follow the above operation, UE multiplexes A-CSI only on the first PUSCH repetition similar to Rel. 15/16.

**Agreement**

For multi-TRP PUCCH (scheme 1 and 3) and PUSCH (Type A and B) repetition, when the number of repetitions is equal to two, the first and second transmission occasion shall be associated with two TRPs, respectively (two UL beams or Power control parameter sets), regardless of the configured mapping pattern.

* Note: For M-TRP PUSCH type B, the number of repetitions refers to ‘nominal’ repetition.

**Agreement**

The following working assumption is confirmed.

For non-codebook based multi-TRP PUSCH, the first SRI field is used to determine the entry of the second SRI field which only contains the SRI(s) combinations corresponding to the indicated rank (number of layers) of the first SRI field. The number of bits, *N2*, for the second SRI field is determined by the maximum number of codepoint(s) per rank among all ranks associated with the first SRI field. For each rank x, the first *Kx* codepoint(s) are mapped to *Kx* SRIs of rank x associated with the first SRS field, the remaining (2N2-*Kx*) codepoint(s) are reserved.

**Agreement**

For type 2 CG based multi-TRP PUSCH repetition:

* The first (legacy) RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ are associated with the first SRS resource set.
* The second (new) RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ are associated with the second SRS resource set.
* Applying the first, second, or both first and second RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ is determined from the new DCI field (for dynamic switching) of the activating DCI similar to the case of DG-PUSCH.

**Agreement**

Confirm the Working Assumption (with supporting two bits for the new field).

* For indicating STRP/MTRP dynamic switching for non-CB/CB based MTRP PUSCH repetition,
  + Introduce a new field in DCI to indicate at least the S-TRP or M-TRP operation.
  + The new field is 2 bits

**Agreement**

For the new field in the DCI for dynamic switching, support Alt.1 (modified).

**Alt.1**

* Support 2 bits with the following combinations.

|  |  |  |
| --- | --- | --- |
| **Codepoint** | **SRS resource set(s)** | **SRI (for both CB and NCB)/TPMI (CB only) field(s)** |
| 00 | s-TRP mode with 1st SRS resource set (TRP1) | 1st SRI/TPMI field (2nd field is unused) |
| 01 | s-TRP mode with 2nd SRS resource set (TRP2) | 1st SRI/TPMI field (2nd field is unused) |
| 10 | m-TRP mode with (TRP1,TRP2 order)  1st SRI/TPMI field: 1st  SRS resource set  2nd SRI/TPMI field: 2nd SRS resource set | Both 1st and 2nd SRI/TPMI fields |
| 11 | m-TRP mode with (TRP2,TRP1 order)  1st SRI/TPMI field: FFS  2nd SRI/TPMI field: FFS | Both 1st and 2nd SRI/TPMI fields |

* The SRS resource set with lower ID is the first SRS resource set, and the other SRS resource set is the second SRS resource set.
  + For codebook and non-codebook usage, respectively
* ~~The same number of SRS resource shall be configured in the two SRS resource sets.~~

**Agreement**

For SP-CSI report on mTRP PUSCH repetition Type A and B activated by a DCI, further study the use of a similar mechanism to A-CSI multiplexing on M-TRP PUSCH without a TB, which includes the following,

* When SP-CSI multiplexed on m-TRP PUSCH, SP-CSI multiplexed on the two repetitions associated with the two TRPs, and the number of repetitions is always assumed to be 2, regardless of the value indicated.
* Reuse similar conditions (e.g. UCIs other than the A-CSI are not multiplexed, same number for first actual repetitions, the content of the CSI is the same) to support SP-CSI multiplexing on m-TRP PUSCH as defined in A-CSI multiplexing on M-TRP PUSCH.

**Agreement**

* To support per TRP closed-loop power control for PUCCH with DCI formats 1\_1 / 1\_2, a second TPC field can be configured via RRC.
* When the second field is configured by RRC, a second TPC field (similar to the existing TPC field) is added in DCI formats 1\_1 / 1\_2 (option 3).
  + Each TPC field is for each closed-loop index value respectively
    - FFS: Whether or not the mapping between the TPC field and the PUCCH transmissions is needed
* When the second field is not configured by RRC, a single TPC field (the existing TPC field) is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for the closed loop index(es) for the scheduled PUCCH
* To support per TRP closed-loop power control for PUSCH with DCI formats 0\_1 / 0\_2, adopt the same solution as with M-TRP PUCCH schemes.
  + FFS: any additional considerations
* Support UE to report the capability on whether it supports the second TPC field
* Note1: Per TRP closed-loop power control is only applicable when the “closedLoopIndex” values are not the same for TRPs.

**Agreement**

For single-DCI based M-TRP PUSCH repetition schemes, when one SRS resource per SRS resource set is configured (i.e., when two SRI fields are absent in DCI formats 0\_1 / 0\_2), default P0, alpha, PL-RS, and closed loop index is defined per TRP. Select one from the following in RAN1 #106-e meeting,

* Alt.1
  + The first P0/alpha, PL-RS, and closed loop index are determined by *sri-PUSCH-PathlossReferenceRS-Id*, *sri-P0-PUSCH-AlphaSetId*, and *sri-PUSCH-ClosedLoopIndex* mapped to the first *sri-PUSCH-PowerControl* associated with the first SRS resource set.
  + The second P0/alpha, PL-RS, and closed loop index are determined by *sri-PUSCH-PathlossReferenceRS-Id*, *sri-P0-PUSCH-AlphaSetId*, and *sri-PUSCH-ClosedLoopIndex* mapped to the first *sri-PUSCH-PowerControl* associated with the second SRS resource set.
  + Note: How to design the signaling link *sri-PUSCH-PowerControl with*two SRS resource sets is up to RAN2.
* Alt.2
  + The first set of values {the first value in P0-AlphaSet, the PL-RS corresponded to *PUSCH-PathlossReferenceRS-Id* = 0 and closed-loop index l = 0} can be used for TRP1, and the second set of values {the second value in P0-AlphaSet, the PL-RS corresponded to *PUSCH-PathlossReferenceRS-Id* = 1 and closed-loop index l = 1 if  *twoPUSCH-PC-AdjustmentStates* is configured, *l*=0 otherwise } can be used for TRP2.
  + Note: How to design the signaling link sri-PUSCH-PowerControl with two SRS resource sets is up to RAN2.
* Alt.3
  + If the UE is provided*enablePL-RS-UpdateForPUSCH-SRS*, the first set of values {the first value in *P0-AlphaSet*, the PL-RS corresponding to the first *sri-PUSCH-PowerControl* associated with the first SRS resource set and closed-loop index *l* = 0} is used for TRP1, and the second set of values {the second value in *P0-AlphaSet*, the PL-RS corresponding to the first *sri-PUSCH-PowerControl* associated with the second SRS resource set and closed-loop index *l* = 1 if  *twoPUSCH-PC-AdjustmentStates* is configured, *l*=0 otherwise} is used for TRP2.
  + Otherwise, the first set of values {the first value in *P0-AlphaSet*, the PL-RS with *PUSCH-PathlossReferenceRS-Id=0* and closed-loop index *l* = 0} can be used for TRP1, and the second set of values {the second value in P0-AlphaSet, the PL-RS with *PUSCH-PathlossReferenceRS-Id*= 1 and closed-loop index *l* = 1 if  *twoPUSCH-PC-AdjustmentStates* is configured, *l*=0 otherwise } can be used for TRP2.
  + Note: How to design the signaling link sri-PUSCH-PowerControl with two SRS resource sets is up to RAN2.

**For further study in future meetings:**

For PHR reporting related to M-TRP PUSCH repetition, study following aspects related to option 4,

* Option 4: Calculate two PHRs (at least corresponding to the CC that applies m-TRP PUSCH repetitions), each associated with a first PUSCH occasion to each TRP, and report two PHRs.
* FFS1: How the PHRs are calculated for reporting (actual PHR or virtual PHR)
* FFS2: How the PHRs are calculated for reporting for other CCs if the multi-cell PHR MAC CE is applied.
* FFS3: Required changes to triggering conditions including the required higher layer parameters (e.g.,’phr-PeriodicTimer’, ‘phr-ProhibitTimer’, ‘phr-Tx-PowerFactorChange’ as TRP specific).
* FFS4: Report P-MPR and MPE per TRP within the same MAC-CE extension.

Note: Down-selection between Options 1-5 will be based on this study as well as the trade-off between benefit versus UE complexity.

### 106-e (August 2021)

**Agreement**

When DCI schedules a retransmission of CG-PUSCH for type 1 CG or type 2 CG (DCI with CRC scrambled with CS-RNTI and NDI=1) while the CG configuration is RRC-configured with two fields of power control parameters, apply the same procedure as DCI activation for CG type 2 agreed before, i.e.,

* The first (legacy) RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ are associated with the first SRS resource set.
* The second (new) RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ are associated with the second SRS resource set.
* Applying the first, second, or both first and second RRC-configured fields ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’ is determined from the new DCI field (for dynamic switching) of the activating DCI similar to the case of DG-PUSCH.

**Agreement**

When fallback DCI (DCI format 0\_0) activates a type 2 CG or schedules a retransmission of a type 1 or type 2 CG, and the CG configuration is RRC-configured with 2 sets of power control parameters (two ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’):

* The UE uses the first set of values for power control (first RRC-configured ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’).

**Agreement**

When a DCI that includes the new 2-bits DCI field for dynamic switching activates a type 2 CG or schedules a retransmission of a type 1 or type 2 CG, and the CG configuration is RRC-configured with only one set of power control parameters (one ‘*p0-PUSCH-Alpha*’ and ‘*powerControlLoopToUse*’):

* The UE expects the new DCI field for dynamic switching is set to “00”, and all PUSCH repetitions are associated with the first SRS resource set.

**Agreement**

For the new field in DCI for dynamic switching,

* For Codepoint “11”, the 1st SRI/TPMI field associate with the 1st SRS resource set while the 2nd SRI/TPMI field associate with the 2nd SRS resource set. i.e.,

|  |  |  |
| --- | --- | --- |
| **Codepoint** | **SRS resource set(s)** | **SRI (for both CB and NCB)/TPMI (CB only) field(s)** |
| 11 | m-TRP mode with (TRP2,TRP1 order)  1st SRI/TPMI field: 1st  SRS resource set  2nd SRI/TPMI field: 2nd SRS resource set | Both 1st and 2nd SRI/TPMI fields |

* For Codepoint “11”, the first repetition in time is associated with the second SRS resource set, and the remaining repetitions follow the configured mapping pattern (cyclic or sequential).
* For Codepoint “10”, the first repetition in time is associated with the first SRS resource set, and the remaining repetitions follow the configured mapping pattern (cyclic or sequential).

**Agreement**

For PHR reporting related to M-TRP PUSCH repetition, support Option 4 as UE optional capability for a UE that supports mTRP PUSCH,

* Option 4: Calculate two PHRs (at least corresponding to the CC that applies m-TRP PUSCH repetitions), each associated with a first PUSCH occasion to each TRP, and report two PHRs.

**Agreement**

For SP-CSI report on mTRP PUSCH repetition Type A and B activated by a DCI, support the use of a similar mechanism to A-CSI multiplexing on M-TRP PUSCH without a TB, which includes the following,

* When SP-CSI multiplexed on m-TRP PUSCH, SP-CSI multiplexed on the two repetitions associated with the two TRPs, and the number of repetitions is always assumed to be 2, regardless of the value indicated.
* For mTRP PUSCH repetition Type A, or for the first PUSCH after activation for PUSCH repetition Type B**,** reuse similar conditions to support SP-CSI multiplexing on m-TRP PUSCH as defined in A-CSI multiplexing on M-TRP PUSCH, i.e.,
  + The UE is expected to follow the above operation for transmitting SP-CSI on two PUSCH repetitions only if
    - For the first PUSCH after activation for PUSCH repetition Type B, the first and second nominal repetitions are expected to be the same as the first and second actual repetitions, respectively (no segmentation).
    - For PUSCH repetition Type A and B, UCIs other than the SP-CSI are not multiplexed on any of the two PUSCH repetitions.
  + When the UE does not follow the above operation, UE transmits SP-CSI only on the first PUSCH repetition similar to Rel. 15/16.
* For subsequent PUSCHs after activation (without corresponding PDCCH) for PUSCH repetition Type B, use the following criteria,
  + If the first / second nominal repetition is not the same as the first / second actual repetition, the first / second nominal repetition is dropped
    - If one of the first or second nominal repetitions is not dropped, SP-CSI is multiplexed on that repetition
  + Else (the first and second nominal repetitions are the same as the first and second actual repetitions)
    - If UCIs other than the SP-CSI are not multiplexed on any of the two PUSCH repetitions, SP-CSI is multiplexed on both repetitions.
    - Otherwise, UE transmits SP-CSI only on the first PUSCH repetition similar to Rel. 15/16 (and the second repetition is dropped)

**Agreement**

For indicating per-TRP OLPC set in DCI format 0\_1/0\_2, if no SRI field presents in the DCI,

* Use the existing field (1 or 2 bits) for OLPC set indication and the second p0-PUSCH-SetList-r16.
  + if value of the field equals to ‘0’ or ‘00’, the UE determine two values of P0 for two TRPs (one P0 value for each TRP) from the first and the second default P0 values.
    - Note: per TRP default P0 values to be decided in separate discussion (alt.1, alt.2, alt.3 in default power control parameter sets).
  + if value of the field equals to ‘1’ or ‘01’, the UE determine two values of P0 for two TRPs (one P0 value for each TRP) from the **first value** in the first *P0-PUSCH-Set-r16\_list* and the **first value** in the **second** *P0-PUSCH-Set-r16\_list*.
  + if value of the field equals to ‘10’ or ‘11’, the UE determine two values of P0 for two TRPs (one P0 value for each TRP) from the **second value** in the first *P0-PUSCH-Set-r16\_list* and the **second value** in the **second** *P0-PUSCH-Set-r16\_list.*

**Working assumption**

For non-codebook based multi-TRP PUSCH repetition, select Alt.2.

* Alt. 2: the actual number of PT-RS ports corresponding to the 1st SRS resource set can be different from the actual number of PT-RS ports corresponding to the 2nd SRS resource set.
* FFS: Whether specification change is needed due to this working assumption

**Agreement**

For RV mapping of type 1 or type 2 CG based multi-TRP PUSCH repetition, support,

* the configured RV sequence (via “*repK-RV*”) is applied separately for PUSCH repetitions corresponding to the first TRP and the second TRP with a an RV offset for the starting RV corresponding to the second TRP (similar to the case of dynamic multi-TRP PUSCH repetition).
* if *startingFromRV0* set to ‘on’, support that the initial transmission of a transport block may start at:
  + the first RV0 transmission occasion of any TRP if the configured RV sequence is {0 2 3 1},
  + any of the transmission occasions of the K repetitions that are associated with RV = 0 if the configured RV sequence is {0 3 0 3}, (same as Rel-15/16).
  + any of the transmission occasions of the K repetitions if the configured RV sequence is {0,0,0,0}, except the last transmission occasion when K≥8. (same as Rel-15/16).
* if *startingFromRV0* set to ‘off’, the initial transmission of a transport block may only start at the first transmission occasion of the K repetitions (same as Rel-15/16).

**Agreement**

For option 4, support the following:

When PHR MAC-CE is reported in slot n, for a CC that is configured with mTRP PUSCH repetition, PHR value(s) are determined as,

* The first PHR value is reported same as Rel. 15/16.
* If the first PHR value is actual PHR (based on Rel. 15/16) corresponding to a repetition among mTRP PUSCH repetitions associated with a given TRP, the second PHR value, select Alt. 1A or Alt. 2A
  + Alt.1A: Is always actual. When there are more than one repetitions associated with the other TRP, the second PHR is calculated considering on the following repetition,
    - If there are repetition(s) towards the other TRP which transmit after the repetition used to calculate first PHR, the UE select the earliest repetition among them.
    - Otherwise, the UE select the latest repetition which transmitted before the repetition used to calculate first PHR.
  + Alt.2A: Is actual only when a repetition associated with the other TRP is transmitted in slot n. Otherwise, it is virtual.
    - If there are multiple repetitions associated with the other TRP in slot n, the earliest one in slot n is selected.
* If the first PHR value is actual PHR (based on Rel. 15/16) but not corresponding to a repetition among mTRP PUSCH repetitions (corresponds to sTRP PUSCH), select Alt. 1B or Alt. 2B
  + Alt1B: a second PHR value is reported as virtual PHR.
  + Alt2B: a second PHR is not reported
* If the first PHR value is virtual, select Alt. 1C or Alt. 2C
  + Alt1C: a second PHR value is reported as virtual PHR.
  + Alt2C: a second PHR is not reported
* When second PHR is virtual, it is calculated based on a set of default power control parameters defined for the other TRP (that is not associated with the first PHR)
* Note: the above is applicable to both single entry and multi-entry PHR reports

**Agreement**

For single-DCI based M-TRP PUSCH repetition schemes, when one SRS resource per SRS resource set is configured (i.e., when two SRI fields are absent in DCI formats 0\_1 / 0\_2), per TRP default P0, alpha, PL-RS, and closed loop index is defined by,

* If the UE is provided*enablePL-RS-UpdateForPUSCH-SRS*, the first set of values {the first value in *P0-AlphaSet*, the PL-RS corresponding to the first *sri-PUSCH-PowerControl* associated with the first SRS resource set and closed-loop index *l* = 0} is used for TRP1, and the second set of values {the second value in *P0-AlphaSet*, the PL-RS corresponding to the first *sri-PUSCH-PowerControl* associated with the second SRS resource set and closed-loop index *l* = 1 if  *twoPUSCH-PC-AdjustmentStates* is configured, *l*=0 otherwise} is used for TRP2.
* Otherwise, the first set of values {the first value in *P0-AlphaSet*, the PL-RS with *PUSCH-PathlossReferenceRS-Id=0* and closed-loop index *l* = 0} can be used for TRP1, and the second set of values {the second value in P0-AlphaSet, the PL-RS with *PUSCH-PathlossReferenceRS-Id*= 1 and closed-loop index *l* = 1 if *twoPUSCH-PC-AdjustmentStates* is configured, *l*=0 otherwise } can be used for TRP2.
* Note: How to design the signaling link sri-PUSCH-PowerControl with two SRS resource sets is up to RAN2.

**Agreement**

For option 4, support the following:

* When PHR MAC-CE is reported in slot n, for a CC that is configured with mTRP PUSCH repetition, second PHR value is determined as,
  + If the first PHR value is actual PHR (based on Rel. 15/16) corresponding to a repetition among mTRP PUSCH repetitions associated with a given TRP, the second PHR value, select Alt. 2A
    - Alt.2A: Is actual only when a repetition associated with the other TRP is transmitted in slot n. Otherwise, it is virtual.
      * If there are multiple repetitions associated with the other TRP in slot n, the earliest one in slot n is selected.
  + If the first PHR value is actual PHR (based on Rel. 15/16) but not corresponding to a repetition among mTRP PUSCH repetitions (corresponds to sTRP PUSCH), select Alt. 1B
    - Alt1B: a second PHR value is reported as virtual PHR.
  + If the first PHR value is virtual, select Alt. 1C
    - Alt1C: a second PHR value is reported as virtual PHR.
* Note: It was agreed that when second PHR is virtual, it is calculated based on a set of default power control parameters defined for the other TRP (that is not associated with the first PHR)
* Note: It was agreed that the above is applicable to both single entry and multi-entry PHR reports

**Agreement**

For per-TRP closed-loop power control,

* When the second TPC field is configured and the indicated PUCCH transmission in DCI formats 1\_1/1\_2  (or PUSCH transmission in DCI formats 0\_1/0\_2) is associated with one “*closedLoopIndex*” value for single TRP transmission, the other TPC field associated with the other “*closedLoopIndex*” value is unused.
* Note1: Each TPC field is for each closed-loop index value respectively (i.e., 1st /2nd TPC fields correspond to “*closedLoopIndex*” value = 0 and 1, respectively).
* Note2: When the other TPC field associated with the other “*closedLoopIndex*” value is unused, the unused TPC field is not applied for any legacy procedures of calculating sum of TPC command values.

**Agreement**

For mTRP PUCCH (or PUSCH) repetitions schemes,

* When the second TPC field is configured and the indicated PUCCH transmission in DCI formats 1\_1/1\_2 (or PUSCH transmission in DCI formats 0\_1/0\_2) is associated with the same “*closedLoopIndex*” value for mutli-TRP tranmission, the other TPC field associated with the other “*closedLoopIndex*” value is unused.
* Note: When the other TPC field associated with the other “*closedLoopIndex*” value is unused, the unused TPC field is not applied for any legacy procedures of calculating sum of TPC command values.

**Agreement**

On the number of SRS resource configured in the two SRS resource sets, select one of the following alternatives,

* Alt.1: Support the same number of SRS resources for both CB and NCB based m-TRP PUSCH repetition.
* Alt.2: Support different number of SRS resources for both CB and NCB based m-TRP PUSCH repetition. The first SRS resource set always have the same or larger number of SRS resources than the second SRS resources set.
  + The bit width of the 1st SRI field is determined based on the first SRS resource set
  + FFS: How to interpret “SRI field is present or not present”
* Alt.3: Support different number of SRS resources for both CB and NCB based m-TRP PUSCH repetition. The first SRS resource set always have the smaller, same or larger number of SRS resources than the second SRS resources set.
  + The bit width of the 1st SRI field is determined based on maximum number of SRS resources among two resource sets
  + FFS: How to interpret “SRI field is present or not present”

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**Agreement**

For both CB and NCB based mTRP PUSCH repetition schemes,

* The *SRS-ResourceSets* (the first and second SRS resource sets) applicable for multi-TRP PUSCH scheduled by DCI format 0\_1 and DCI format 0\_2 are defined by the entries of the higher layer parameter *srs-ResourceSetToAddModList* and *srs-ResourceSetToAddModListDCI-0-2* in SRS-config, respectively.
* The first/second SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModListDCI-0-2* is composed of the first *NSRS,0 2* SRS resources in the first/second SRS resource set configured by higher layer parameter *srs-ResourceSetToAddModList*.
  + FFS: Whether the value of the *NSRS,0 2* can be different
* The presence of the new field in the DCI for dynamic switching (2bits) is separately determined for DCI format 0\_1 and DCI format 0\_2 (based on whether two SRS resource sets are configured for that DCI format).

**Agreement**

For CB based mTRP PUSCH repetition, the number of SRS ports indicated by the two SRIs should be the same.

* Note: This is to clarify an older agreement on the indication of two SRIs/TPMIs, where it mentioned that “The number of SRS ports between two TRPs should be same”.
* FFS: Whether or not this has specification impact

**Agreement**

Confirm the following working assumption (*with additional note in RED*)

|  |
| --- |
| For non-codebook based multi-TRP PUSCH repetition, select Alt.2.   * Alt. 2: the actual number of PT-RS ports corresponding to the 1st SRS resource set can be different from the actual number of PT-RS ports corresponding to the 2nd SRS resource set.   Note: Capturing any spec impact related to this is up to the Editor. |

**Agreement**

On the number of SRS resources configured in the two SRS resource sets, select Alt.1,

* Alt.1: Support the same number of SRS resources for both CB and NCB based m-TRP PUSCH repetition.

**Conclusion**

For the indication of  PTRS-DMRS association for maxRank = 2 in mTRP PUSCH repetition type B, the Table used to indicate the association between PTRS port(s) and DMRS port(s) (i.e., Table 7.3.1.1.2-25 or 7.3.1.1.2-26 in 38.212) shall be determined based on legacy procedure (i.e., Tables are associated with the *maxNrofPorts* in *PTRS-UplinkConfig*).

**Agreement**

For a BWP configured with two SRS resource sets for CB or NCB based mTRP PUSCH repetition with Type 1 CG configuration,

* If the CG is configured with only one field for each of ‘*pathlossReferenceIndex*’, *'srs-ResourceIndicator*', '*precodingAndNumberOfLayers*', *'p0-PUSCH-Alpha'* and *'powerControlLoopToUse',*PUSCH repetitions are associated with the first SRS resource set.

**Agreement**

If a UE does not support option 4 (Calculate two PHRs),

* If the PHR reporting is actual PHR, the UE uses the set of power control parameters corresponding to a first (earliest) repetition that overlaps with the first slot in which the PUSCH that carries the PHR MAC-CE is transmitted.
* If the PHR reporting is virtual PHR, it is reported based on legacy procedures.
* Note: RAN2 may further discuss PHR triggering aspects related to mTRP PUSCH repetition

**Agreement**

For NCB based mTRP PUSCH repetition, on the minimal gap between associated NZP-CSI-RS and aperiodic NCB SRS, select one from the below in RAN1 #107-e meeting,

* Alt. 1: If both SRS resource sets are triggered in an overlapped manner in time domain (overlapping refer to overlapping of minimal gaps between two pairs of associated NZP-CSI-RS and aperiodic SRS corresponding to two SRS resource sets), the UE is not expected to update the SRS precoding information if the gap from the last symbol of the reception of the aperiodic NZP-CSI-RS resource and the first symbol of the aperiodic SRS transmission is less than 42 + d OFDM symbols, where d indicates the number of overlapped symbols for the two pairs of associated NZP-CSI-RS and aperiodic SRS for NCB.
  + FFS: value of d
* Alt. 2: UE is not expected to support overlapping precoding calculation for different associated NZP-CSI-RS within a CC, i.e., the UE is not expected to get triggering for two SRS resource sets in an overlapped manner in time domain (overlapping refer to overlapping of minimal gaps between two pairs of associated NZP-CSI-RS and aperiodic SRS corresponding to two SRS resource sets).
  + The minimal gap between associated NZP-CSI-RS and aperiodic SRS is same as Rel-15/16.
* Alt.3: Introduce a UE capability on UE support simultaneous precoding calculation for different associated NZP-CSI-RS within a CC.
  + The minimal gap between associated NZP-CSI-RS and aperiodic SRS is same as Rel-15/16.
* Alt. 4: There is nothing wrong with the legacy procedures and capability indication to handle this issue. No changes to spec.

**Conclusion**

For Rel-17 mTRP PUSCH repetition, the UE may not need to consider following overlapping scenarios,

* One SRS resource for CB collides with another SRS resource for CB.
* One SRS resource for non-CB collides with another SRS resource for non-CB in another resource set.

**Agreement**

For the indication of PTRS-DMRS association for maxRank > 2 in mTRP PUSCH repetition type B, select Option 1

* **Option 1 (4 bits): with a second PTRS-DMRS association field (similar to the existing field), and each field separately indicating the association between PTRS port and DMRS port for two TRPs.**