3GPP TSG RAN WG1 #106-e R1-200xxxx

e-Meeting, August 16th – 27th, 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. The issues discussed by one or two companies are not listed for now.

## 2.1 Summary

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| **Issue** | **Summary from Tdocs** | **Moderator comments** |
| #1. PUCCH/PUSCH Power Control: *TPC command* | Further discussion on “*Each TPC field is for each closed-loop index value respectively*”   * 1st/2nd TPC fields correspond to1st/2nd PUCCH beams, respectively - **Spreadtrum** * 1st/2nd TPC fields correspond to 0/1 closed-loop index, respectively – **CATT, E///** * Mapping between the TPC fields and the PUCCH transmission occasions is not needed - **vivo** * Both TPC fields (4 bits) are jointly used to indicate a single TPC value – **ZTE** * If PUCCH associated with only one closed-loop index (one spatial relation info/power set),   + The other TPC field is unused - **CATT, Fujitsu, Mtek (?)**   + The other TPC field is still valid – **Oppo**   PUSCH related proposals   * When the second SRI field is configured, the TPC field association to a TRP is determined based on the SRI ordering in the DCI – **IDC** * the association rule between the TPC fields and the SRS resource sets should be specified **- Xiaomi**   DCI format 1\_0 (fallback DCI)   * For TPC command in DCI format 1\_0, if the indicated PUCCH resource is associated with two “*closedLoopIndex*” values for multi-TRP PUCCH transmission schemes, single TPC field in DCI formats 0\_1 is applied to both closed loop indices for the scheduled PUCCH. - **QC**   Other  If the UE is not provided *tpc-Accumulation* and DCI formats 0\_1 / 0\_2 indicates the single-TRP mode, then the UE expects the TPC field not associated with the SRI indicates 0 dB accumulation. - **MTek** | In the earlier RAN1 meeting, it was mentioned that “*Each TPC field is for each closed-loop index value respectively* “, so it should be clear that 1st/2nd TPC fields correspond to closed-loop index = 0 and 1, respectively. FL do not think any new agreement needed on that.  On the “*FFS: Whether or not the mapping between the TPC field and the PUCCH transmissions is needed*”, there is not enough support to introduce any new mapping between TPC fields and PUCCH transmissions.  For the case of PUCCH associated with single closed loop index, several companies wanted to clarify that the other TPC field (associated with other closed loop index) is not used. This seems an open point.  For the suggestion on SRI field-TPC field association, that may not be needed as closed loop indices are associated with TPC fields.  Last meeting agreement is limited to DCI format 1\_1/1\_2 and shall be extended to DCI format 1\_0 as m-TRP PUCCH repetition mainly depend on the indicated PUCCH resource, not on the DCI format.  See FL proposal 2.1. |
| #2: Default beam for PUSCH | * PUCCH with lowest ID having two spatial relation info, selects the one with lower ID (majority): **ZTE, vivo, Lenovo, CATT, Oppo, QC, CMCC, MTek, Apple, DCM** * PUCCH resource with the lowest ID cannot be activated with two spatial relation info: **QC** * No issue to define anything in the specs : **E///** | Also discussed during the last two RAN1 meetings. During the RAN1 #105-e meeting, there was only two companies had concerns. The FL proposal is from the last meeting.  See FL proposal 2.2 |
| #3: Mapping pattern: Scheme 1 (or m-TRP PUSCH repetition) with Frequency hopping | * Option 1: **Lenovo, CATT, SS, E///, QC, Apple, Xiaomi** * Option 2: * Option 3: **HW, vivo, MTek**   Related discussion in PUSCH   * Support beam mapping per frequency hop when inter-slot frequency hopping is configured - **vivo** * Perform frequency hopping among the PUSCH repetitions with the same beam – **Lenovo, CATT, Fujitsu, E///, LG, Xiaomi** | Discussed during last two RAN1 meetings. Even though majority propose option 1 in this meeting, concerns on option 1 were raised by MediaTek, HW, IDC, vivo, Spreadtrum, OPPO, TCL, NEC, Nokia, FW, Intel. We could try one last time.  If RAN1 agree the operation to PUCCH, a similar framework can be extended to PUSCH.  See FL proposal 2.3 |
| #4: PUCCH grouping | * Support activating two spatial relation info’s (for FR2) for a group of PUCCH resources in a CC – **vivo, QC, Apple, LG, ZTE, CATT, CMCC, Nokia (**three options listed**), DCM** * Support activating two sets of power control parameters (for FR1) for a group of PUCCH resources in a CC – **vivo, QC, Apple, LG** * Support that one PUCCH resource can be configured in two PUCCH Groups which correspond to two beams/TRPs in FR2. – **ZTE** | There is good alignment on supporting the activation of two spatial relation info’s for a group of PUCCH resources in a CC. Also, some companies suggest extending this feature to FR1.  On the exact solution how to do this, there is not much input, but it seems that extending the Rel-16 like method can be adopted.  See FL proposal 2.4 |
| #5: Scheme 1/3: Repetition numbers | Scheme 1 - PUCCH formats 1/3/4: 16 **(CATT, E///**)  Scheme 1 - PUCCH format 0/2: 4, 8, and 16 (**E///)**  Scheme 3: 2, 4, 8 (**vivo**) | This was discussed with no agreement last two meetings. No FL proposal. |
| #6: M-TRP intra slot beam hopping (Scheme 2) | Support Scheme 2:   * Yes: HW, ZTE, vivo, Fujitsu, QC, LG, Xiaomi | This was discussed multiple meetings. No consensus even in the last meeting. No FL proposal. |
| #7: Other issues: switching of scheme, UCI multiplexing | * Support enhancements on UCI multiplexing for multi-TRP based PUCCH repetition in Rel-17 - **HW** * Rel-15/16 collision handling between PUCCH repetition and other channels/signals are also applied also for M-TRP schemes – **ZTE, E///** * Only the first PUCCH considered when intra-slot PUCCH repetitions overlap with a same PUCCH in multiple sub-slots – **TCL** * Support dynamic switching between the different multi-TRP PUCCH schemes. – **Nokia** * For multi-TRP PUCCH operation in FR1, send an LS to RAN2, (containing all corresponding RAN1 agreements and suggest that the maximum number of 8 power control parameters sets) - **Nokia** | From FL perspective, UCI multiplexing does not have to address separately for M-TRP as Rel-15/16 behaviors can be reused at least for Scheme 1. For Scheme 3, as Rel-17 IIoT also discuss intra-slot repetition for s-TRP, any UCI multiplexing related issues can be discussed there. No FL proposal.  The issue on dynamic switching is not supported by many and also depend on Rel-17 IIoT discussion on intra-slot PUCCH repetition. No FL proposal.  A LS to RAN2 can be sent with all the agreement made so far. FL proposal will be added on this in the phase 2 discussion. |

## 2.2 Feature lead Proposals

### Power control: TPC

**Proposal 2.1:** 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.
  + Note: 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).
* 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | **Support the proposal.**  **For the first bullet: We also do not see the need for optimizations in the case of one closedLoopIndex.**  **For the second bullet: Unlike mTRP PUSCH, mTRP PUCCH only depends on PRI field which exists also in fallback DCI. Hence, the proposal is needed.** |
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Default beam for PUSCH

**Proposal 2.2:** 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | **Support. We are also ok with the restriction. Either way, a clear UE behavior or restriction is needed in our view.** |
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### Scheme 1 - Frequency hopping and beam mapping

**Proposal 2.3:** When inter-slot frequency hopping is configured with Scheme 1, support the following,

* 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | **Support the proposal.**  **As explained before, the benefit in the case of cyclical mapping is opportunistic early termination. We are also ok with gNB to configure whether frequency hopping is at slot level or among the repetitions with the same beam for cyclical mapping.** |
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### Grouping of PUCCH resources

**Proposal 2.4:** 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, 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, 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | **Support the proposal, which is the simplest way to update two beams for a group of PUCCH resources in our view. Up to 4 groups is supported in Rel. 16, which is sufficient in our view.** |
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## 2.3 Additional high priority proposals

If companies wish to bring any additional aspects related to PUCCH during RAN1 #106-e, please comment below.

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| Company | Comments |
| QC | PUCCH Scheme 2 is high priority. In the previous meeting, some companies asked for evaluations. We provided detailed and extensive evaluations in our contribution this time. Also, we explained the benefits of this scheme over Scheme 1 or Scheme 3, which are very important (e.g., UCI multiplexing and multiplexing UCI on PUSCH, which are not possible in Scheme 1 or 3).  In term of specification impact, our understanding is that agreeing to reusing frequency hopping mechanisms would be enough (very minor spec impact). In other words, the following proposal is enough for the functionality of Scheme 2:  **Proposal: Support intra-PUCCH resource beam-hopping (Scheme 2):**   * **Reuse frequency hopping mechanisms for number of symbols in the first / second beam-hops, and number of DMRS symbols and locations.** |
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# Multi-TRP PUSCH transmission

The remaining open issues and company views are summarized below. The topics discussed by one/two companies or proposals not aligned with earlier RAN1 agreements are not listed to simplify the summary.

## 3.1 Summary

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| **Issue** | **Summary from Tdocs** | **Moderator comments** |
| #1: Power control: OLPC | The case of “SRS resource indicator is not present”   * Number of OLPC fields * Support a second OLPC set indication field in DCI - **ZTE** * Single OLPC field with bit width of 3 bits can be supported – **vivo** * No change in the OLPC set indication field – **SS, CATT, QC, Intel, DCM, Xiaomi** * Interpretation of field(s) * if value of the field equals to '0' or '00', the UE determines two P0 values for two TRPs from the first and second values in 'P0-PUSCH-AlphaSet', respectively. * if value of the field equals to '1' or '01', the UE determines two P0 values for two TRPs from the first value in two 'P0-PUSCH-Set-r16', respectively. * if value of the field equals to '10', the UE determines two P0 values for two TRPs from the second value in two 'P0-PUSCH-Set-r16', respectively. – **SS, CATT, QC, Intel** (‘0’/’00’ is related to default power control parameter set discussion**), DCM, Xiaomi** | A majority of companies support to reuse the same OLPC field and introducing a second “P0-PUSCH-Set-r16”. This is also aligned with the earlier agreement related to the case of “SRS resource indicator is present”.  On the interpretation of the field, there is good alignment between companies on how the field values are interpreted.  One company mentioned that “0” and “00” interpretation may depend on the decision on default power control (At.1-Alt.3) for m-TRP. From FL observation, extending the Rel-16 mechanism seems to be having more support within this discussion and does not have bind to the other discussion.  See FL proposal 3.1 |
| #2: Power control: Default PC parameters | Default PC parameters when SRI fields are absent:   * Alt.1: (7) **IDC, FW, Oppo, E///, QC, Xiaomi, Nokia, TCL** * Alt.2: (5) **Spreadtrum, Fujitsu, CMCC, Intel, DCM** * Alt.3: (8) **ZTE, vivo, Lenovo, Spreadtrum, CATT, CMCC, Fraunhofer, LG** | Companies views are different. From FL perspective, we can remove Alt.2 and down-select among Alt.1 and Alt.3.  See FL proposal 3.2 |
| #3: Power control: PHR reporting | * Option 1: (1) **QC** * Option 2: (5) **ZTE, (SS)**, (**FGI/APT), (LG), (ASUSTeK)** * Option 4: (12) **HW, IDC, SS,** **FGI/APT, E///, MTek, Apple, LG, Xiaomi, Covinda, ASUSTeK, Nokia** * Option 5: (1) **FW, QC**   Company views on open items (related to Option 4):  *FFS1: How the PHRs are calculated for reporting (actual PHR or virtual PHR)*   * Report always two PHRs (TRP1, TRP2) if PHR is triggered in least one TRP. – **vivo**   + If PUSCH scheduled by DCI is only toward TRP1, report actual PHR for TRP1 and virtual PHR for TRP2. – **vivo, HW, Oppo**   + If PUSCH scheduled by DCI is toward TRP1 and TRP2,     - report actual PHRs for TRP1/TRP2 - **vivo, HW, Nokia, Intel, Apple (**if both beams transmitted in same slot**)**     - report actual PHR and virtual PHR for TRP1 and TRP2, respectively. **Apple (**if TRP2 transmission in different slot**)** * Do not report PHR (TRP1 and/or TRP2) if PHR triggered in one TRP but that is not having PUSCH scheduled by DCI - **HW** * Actual PHR is calculated based on the first PUSCH occasion towards the PUSCH-receiving TRP while virtual PHR is calculated based on a set of default power control parameters defined for the non-receiving TRP. – **vivo, Apple**   *FFS2: How the PHRs are calculated for reporting for other CCs if the multi-cell PHR MAC CE is applied.*   * If the PUSCH carrying PHR in one CC overlap with M-TRP PUSCH repetitions of other CCs, actual PHR is reported for the TRP(s) with overlapping PUSCH(s) **– E///(?), HW, vivo** * If the PUSCH carrying PHR in one CC overlap with M-TRP PUSCH repetitions of other CCs, virtual PHR is reported for the TRP with non-overlapping PUSCH(s) – **HW, vivo** * For any combination of overlapping PUSCH with other CC, the actual PHR is calculated based on the first PUSCH transmission associated with one TRP and virtual PHR is calculated for another TRP. – **Oppo** * If the DCI scheduling mTRP PUSCH repetition doesn’t satisfy the timeline condition for multi-cell PHR, the UE can calculate virtual PHR per TRP based on the default PUSCH power control parameter per TRP on the CC. – **SS**   *FFS3:* *Required changes to triggering conditions including the required higher layer parameters (e.g.,’phr-PeriodicTimer’, ‘phr-ProhibitTimer’, ‘phr-Tx-PowerFactorChange’ as TRP specific).*   * Configure ’phr-PeriodicTimer’, ‘phr-ProhibitTimer’, ‘phr-Tx-PowerFactorChange’ as TRP specific.   + Yes – **ZTE**   + No – **vivo**, **FGI/APT** * clarify pathloss change exceeding phr-Tx-PowerFactorChange is calculated between pathloss measured by PL-RS from the same TRP and one of the transmission occasions can trigger the PHR report – **vivo, IDC** * For Option 4, a PHR is triggered if the required power backoff for any of the two TRPs in a cell has changed more than phr-Tx-PowerFactorChange dB since the last transmission of PHR. – **MTek** * For Option 4, if mpe-Reporting-FR2 is configured, a PHR is triggered if the existing triggering conditions are satisfied by any of the two TRPs in a cell - **MTek**   *FFS4:* *Report P-MPR and MPE per TRP within the same MAC-CE extension.*   * Support reporting of P-MPR and MPE per TRP   + Yes – **MTek, Nokia**   + No – **vivo** | There is a majority support for Option 4. Even though option 2 has some support, several companies (4 out of 5) are OK with option 4. FL thinks that RAN1 can go ahead with supporting Option 4.  See FL proposal 3.3-1  On the details of option 4, there are several inputs for multiple companies. However, FL could not find any common view among multiple companies who provided inputs.  FL has the following high-level observations in company inputs.   * For single entry PHR reporting, reported PHRs may depend on DCI scheduling m-TRP mode and s-TRP mode. * For multi entry PHR reporting, reported PHRs may depend on the overlapping scenarios of PUSCH carried in different CCs. * For TRP specific triggering conditions, not many companies believe that TRP specific triggering should be supported. * For TRP specific P-MPR and MPE reporting, not many inputs*.*   Anyways, FL suggests companies to provide further inputs and details considering the suggested proposal by the FL.  See FL question 3.3-2. |
| #4. PTRS-DMRS association | PTRS-DMRS association for maxRank > 2   * Option 1 (4 bits): (2) **QC, Apple (**CB scheme**), Xiaomi** * Option 2 (2 bits): (2) **ZTE, QC** * Option 3 (2 bits): (7) **vivo, SS, CATT, Oppo, E///, Intel, LG** * Other suggestions: new MAC-CE (**Spreadtrum**), no change to legacy (**QC, LG**), fixed association for NCB (**Apple**)   Other  For maxRank = 2, PTRS-DMRS association field should be interpreted differently according to the total number of PTRS ports and the actual number of PTRS ports that is indicated by SRI or TPMI. - **SS** | The majority of companies support Option 3 in this meeting. However, RAN1 tried to agree on different options in the last meeting, and there were 4 companies objecting to Option 1 and 9 companies were objecting to Option 3.  FL point of view, the situation may not change as several companies already dropped the discussions in their contributions.  For the clarification purpose, we can conclude that legacy behaviors are applied.  See FL proposal 3.4 |
| #5. SP CSI on M-TRP PUSCH repetition | Support multiplexing SP-CSI on MTRP PUSCH repetitions   * Yes – **Fujitsu, E///, Intel, QC, Nokia, TCL** * No – **ZTE**   Other details   * Define the UE behaviour for subsequent PUSCHs after activation (without corresponding PDCCH) for PUSCH repetition Type B. - **QC** | Several companies provided inputs to support multiplexing SP-CSI on MTRP PUSCH based on a similar approach as adopted in multiplexing A-CSI on MTRP PUSCH.  Also, QC provide details on multiplexing SP-CSI on subsequent PUSCHs (after activation). From FL perspective, the discussion on multiplexing SP-CSI on PUSCH coming after activation is related and RAN1 shall conclude details on that.  See FL proposal 3.5 |
| #6. DCI field on dynamic switching | Discussion of codepoint = ‘11’,   * Alt 1: the 1st SRI/TPMI field associate with the 2nd SRS resource set while the 2nd SRI/TPMI field associate with the 1st SRS resource set – **Oppo, FGI/APT, E///, Nokia** * Alt 2: 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 - **vivo , Lenovo, CATT, SS, NEC, QC, MTek, Intel, Apple, DCM, Xiaomi**   Other proposals   * If the new 2-bit field is not configured, one or more entries in 2nd SRI filed for NCB and 2nd TPMI field for CB can be used to indicate STRP/MTRP dynamic switching. - **ZTE** * The bit width of the 1st SRI field is determined based on the maximum number of SRS resources in the two SRS resource sets and the bit width of the 2nd SRI field is determined based on the number of SRS resource(s) in the 2nd SRS resource set. – **Lenovo, CATT** * For the two SRS resource sets configured with usage of “nonCodebook”/“codebook”, the number of SRS resources in the first SRS resource set is expected to be no less than the number of SRS resources in the second SRS resource set. – **CATT** * Only support to configure the same number of SRS resource in two SRS resource sets with usage set to ‘codebook’ or ‘non-codebook’. – **Oppo, LG, Xiaomi, Nokia** | On the discussion related to codepoint = ‘11’, the majority support Alt.2. However, even among the companies who support Alt.2, there seems to be different interpretation on how the SRS resource sets are mapped to repetitions.  Several companies also discussed the issue of same/different number of SRS resources in resource sets and argued that Alt.2 allows the possibility of having different number of SRS resources. To FL understanding, agreeing to Alt.2 does not fully conclude that different number of SRS resources are supported for TRPs. For example, in non-codebook based PUSCH, we made the following agreement,  Agreement  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.  If the number of resources allowed to be different, the above agreement may not fully work as 2nd SRI field depend on the first SRI field.  See FL proposal 3.6 |
| #7. NCB based PUSCH: number of PT-RS ports | For non-codebook based multi-TRP PUSCH repetition, down-selection one of the two alternatives: - **E///**   * Alternative 1: the actual number of PT-RS ports corresponding to the 1st and 2nd SRS resource sets are the same. * Alternative 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. | For non-CB based PUSCH repetition, E/// discussed a scenario that the actual number of PT-RS ports (derived from SRI indication) coming from two TRPs may be different. From FL perspective, this seems a valid issue for discussion.  See FL proposal 3.7 |
| #8. M-TRP CG PUSCH repetition: RV mapping | RV sequence   * 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) – **CATT, NEC, E///, QC, Fraunhofer, Intel, Nokia** * Configure two RV sequences **– Xiaomi, TCL**   Discussion on ‘startingFromRV0’   * if *startingFromRV0* is set to ‘on’, support that the initial transmission can start also from the first transmission occasion and/or any transmission occasions associated with RV=0 for the second TRP. – **NEC, Xiaomi,** **Oppo, LG (**for {0 2 3 1}**), TCL, Fujitsu** * For CG based multi-TRP PUSCH repetition, if *startingFromRV0* is set to 'off', the initial transmission of a TB may start at the first transmission occasions associated with different UL beams. – **TCL** * support enhancement on starting RV per TRP to enable reception of sufficient number of PUSCH repetitions at each TRP - **Nokia** | RAN1 #105-e also had good alignment for supporting a single RV sequence for CG PUSCH with a configurable offset. FL point of view, RAN1 can start from where we stopped in the last meeting.  Also, on the startingFromRV0, there are several companies providing inputs. From FL perspective, it makes sense to extend the Rel-15/16 framework such that CG PUSCH can start towards any TRP that the transmission occasion is having RV = 0.  See FL proposal 3.8 |
| #9. M-TRP CG PUSCH: configuration details | TRP ordering for CG type 1   * SRS resource set ID can be introduced to rrc-ConfiguredUplinkGrant to mark the target TRP of CG type 1 when only one set of parameters is configured – **vivo** * Introduce the new field for dynamic switching in the “rrc-ConfiguredUplinkGrant” - **Lenovo** * For CG based multi-TRP PUSCH repetition, support alternating TRP orders in different CG PUSCH periods. **– E///**   Retransmission of CG PUSCH   * Discuss the case of 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,– **QC (**apply the same procedure as DCI activation for CG type 2 agreed before),  **Lenovo** * Associate CG fields and SRS resource sets **– E///** * 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’). – **QC** * 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’): **QC** * 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. * Discuss alternatives for power control of CG retransmission - **vivo** | Optimizing (such as TRP ordering and alternating TRP order) m-TRP CG type 1 PUSCH repetition seems to be less critical from FL perspective. No FL proposal.  The retransmission of CG PUSCH type 1 and type 2, associating SRS resource sets, behaviors for fallback DCI, and several other aspects were discussed in few contributions. Overall, FL sees that suggested proposals from QC are valid and can be discussed.  See FL proposal 3.9-1/2/3 |
| #10. M-TRP CG PUSCH repetition: PTRS-DMRS association | * clarification of UL PT-RS port(s) and DM-RS port(s) for CG type 1 towards multiple TRPs is required - **vivo** * For CG based multi-TRP PUSCH repetition, PTRS is associated with DMRS port 0. – **E///** * support PT-RS to DMRS port association cycling. The associated DMRS port index for a PT-RS port should be selected based on the repetition index. - **Apple** * For Type 1 CG, each PTRS port is associated with the 1st scheduled DMRS port sharing the PTRS port.: **CATT** * For CG-based MTRP PUSCH, the PTRS-DMRS association defined by a value of ‘0’ for the 1-bit DCI field or a value of ‘00’ for the 2-bit DCI field in case of dynamic grant based PUSCH can be used as default. - **Fraunhofer** | In RAN1 #105-e meeting, the following was only had one concerning company.  “**Proposed Conclusion 3.10:** For M-TRP PUSCH corresponding to a configured grant Type 1 transmission, the UE may assume the association between UL PT-RS port(s) and DM-RS port(s) defined by value 0 in Table 7.3.1.1.2-25 or value “00” in Table 7.3.1.1.1.2-26 described in Clause 7.3.1 of [5, TS38.212] (similar to s-TRP CG PUSCH operation).   * No spec impact”   Unless defined otherwise, legacy operation will be applied for m-TRP CG PUSCH repetition. From FL perspective, it is not critical to agree on a conclusion like above, so this discussion is not proposed again. No FL proposal. |
| **#**11. Collision between PUCCH(s) and PUSCH(s) | * When mTRP PUSCH collides with PUCCH, support that UCI can be transmitted in the first actual PUSCH repetition corresponding to each beam. – **Apple** * 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. – **HW** * Listing cases of overlapping PUCCHs/PUSCHs for multi-TRP operation that should be further discussed: **FGI/APT** * Do not support multi-TRP PUSCH enhancements specific for handling the scenarios where at least one of the PUSCH repetitions overlaps with a PUCCH carrying CSI and/or HARQ-ACK. - **Nokia** | From FL perspective, collision handling among PUCCH(s) and PUSCH(s) is not the most critical discussion in this agenda. Can come back to this later. No FL proposal. |
| #12. Other | * Support two default beams and two default pathloss reference RSs for two SRS resource sets configured for PUSCH and further study how to determine two default beams and two default pathloss reference RSs. – **Lenovo** * The default beam and default pathloss reference RS of a PUSCH is determined according to the new field which indicates with which SRS resource set(s) the PUSCH is associated. - **Lenovo** * The first and second SRI of indicated SRIs in slot n can be associated with the most recent transmission of SRS resources in the first and second SRS resource sets, respectively, identified by the SRI, where the SRS resources are prior to the PDCCH carrying the SRI. – **SS** * A dynamic indication (e.g., a DCI field or an entry in TDRA table) for adapting between cyclical and sequential beam mapping patterns should be considered. – **FGI/APT** * Consider per TRP, rather than per BWP, configuration (e.g., invalid symbol pattern) for multi-TRP operation. – **FGI/APT** * For multi-TRP PUCCH schemes, if the UE is not provided *pathlossReferenceRSs*, define how to calculate two pathloss values – **Nokia, TCL,** | Can come back to this later. No FL proposal. |

## 3.2 Feature lead Proposals

OLPC set indication

**Proposal 3.1:** 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 *P0-PUSCH-AlphaSet* in *p0-AlphaSets*.
  + 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.*

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Support the proposal other than the first bullet. The first bullet depends on the outcome of Proposal 3.2. |
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Default PC parameters

**Proposal 3.2:** 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,

* 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.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.

Please comment on preferred alternative to down select.

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| **Company** | **Comments** |
| **QC** | Support Alt1. In our understanding, Alt1 is both the simplest and most flexible way (up to gNB how to configure). Alt2/3 force to use two closed loops while the gNB may prefer to not use both closed loops for this purpose (i.e., may want to use the two closed loops for eMBB versus URLLC, or for initial transmission versus retransmission, etc.). In Alt1, this is completely up to the gNB. In addition, Alt1 is a unified way for all ULPC parameters, and we do not think RRC configuration overhead should be concern for mTRP (anyway, RRC configuration is needed for enabling mTRP PUSCH).  It would be good to clarify the benefit of Alt3 given that it is both more complicated and less flexible. |
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PHR reporting

**Proposal 3.3-1:** For PHR reporting related to M-TRP PUSCH repetition, support 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.

**Proposal 3.3-2:** For option 4, support the following,

* For single cell PHR reporting,
  + When PHR is triggered for at least one TRP (TRP1 and/or TRP2) and m-TRP PUSCH repetitions scheduled by the DCI are towards TRP1 and TRP2, the reported two PHRs correspond to TRP1 and TRP2 are actual PHRs.
  + When PHR is triggered for TRP1 and S-TRP PUSCH transmission (or repetitions) scheduled by the DCI is toward TRP1, the reported PHR correspond to TRP1 is an actual PHR and the reported PHR correspond to TRP2 is a virtual PHR.
  + When PHR is triggered for TRP1 but no PUSCH transmission scheduled by the DCI towards TRP1, PHR is not reported.
* For multi cell PHR reporting,
  + When the PUSCH carrying PHR in one CC (CC1) overlap with at least one m-TRP PUSCH repetitions of other CC (CC2),
    - If the overlapping is with m-TRP PUSCH repetitions associated with both TRPs, two actual PHRs are calculated for TRP1 and TRP2 based on the first (earliest) repetition corresponding to each TRP in CC2 that overlaps with the first slot in which the PUSCH carrying PHR in CC1.
    - If the overlapping is with m-TRP PUSCH repetitions associated with one TRP (TRP1), the actual PHR is calculated for TRP1 based on the first (earliest) repetition in CC2 that overlaps with the first slot in which the PUSCH carrying PHR in CC1, and virtual PHR is calculated for the other TRP (TRP2).
  + When the PUSCH carrying PHR in one CC (CC1) does not overlap with at least one M-TRP PUSCH repetitions of other CC (CC2), legacy procedure applied.
* Note: Actual PHR is calculated based on the first PUSCH occasion towards the PUSCH-receiving TRP while virtual PHR is calculated based on a set of default power control parameters defined for the non-receiving TRP.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Do not support Proposal 3.3-1 in the current form due to the concerns explained in our Tdoc (UE complexity, several ambiguities, and specification impacts). Furthermore, as evident from other Tdocs, different companies have different understandings regarding Option 4, and the complexity/spec impact of different proposals are not the same.  Given these concerns, and also the fact that option 4 has majority support, we can accept option 4 if   * Option 4 is optional UE capability. A UE should be able to support mTRP PUSCH repetitions w/o having to support Option 4 for PHR * Option 4 is made simple w/o two actual PHRs unless if both are in the same slot (more explanation regarding this below)   For proposal 3.3-1: Based on the above, we suggest the following to move forwards:  **Proposal 3.3-1:** For PHR reporting related to M-TRP PUSCH repetition, support Option 4 as UE optional capability,   * 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.   If UE does not support Option 4 for PHR, 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) is reported.  For Proposal 3.3.2: Assuming that Option 4 is optional UE capability as suggested above, we are ok with the general direction of this proposal. However, we wanted to mention a few points:   * Regarding “PHR is triggered for at least one TRP” or “PHR is triggered for TRP1”, given that PHR configurations are per cell group (common to all CCs), we prefer to not introduce per-TRP PHR triggering. From the MAC layer perspective, existing triggering mechanisms are enough. Otherwise, there will be significant RAN2 impact. * We prefer to have the same unified design for both non-CA and CA case. Otherwise, we also have to treat two cases for UL-CA differently: Whether mTRP PUSCH carries MAC-CE or another CC carries the MAC-CE * In the current spec, actual overlap of PUSCH with MAC-CE and other PUSCHs is not important. Instead, whether they are in the same slot or not is important. Same principle should be maintained here for the conditions that the second PHR can be actual. * PHR reporting for sTRP CCs or sTRP PUSCHs should not be impacted. * Second PHR value is reported only when the first PHR value is not virtual   Given the above, we suggest to focus on a simple proposal that also reuses Rel. 15/16 mechanisms as much as possible:  **Proposal 3.3-2:** 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 is actual PHR only when a repetition associated with the other TRP is transmitted in slot n.   + Otherwise, the second PHR value is virtual PHR: calculated based on a set of default power control parameters defined for the other TRP (that is not associated with the first PHR) * If the first PHR value is virtual, a second PHR value is not reported |
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PT-RS DMRS association

**Proposed conclusion 3.4:** For single DCI based M-TRP PUSCH Type B repetition, the indication of PTRS-DMRS association for maxRank > 2 is based on the legacy framework, i.e., the same PTRS-DMRS association field is applied to both TRPs (to both sets of repetitions).

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Support the proposal, which is the default assumption in the absence of Options 1-3 (which seemed difficult to converge in the previous meeting) |
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SP-CSI on PUSCH

**Proposal 3.5:** 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 A-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 A-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.
  + Note: The scheduling offset for the first A-CSI should meet the Z and Z’ requirement
* 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).

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Support the proposal, which is consistent with Rel. 16 behavior (For PUSCH repetition Type B, subsequent PUSCHs after activation are not treated the same as the first PUSCH due to the fact that gNB cannot ensure nominal repetitions are never segmented):  For PUSCH repetition Type B, when a UE receives a DCI that schedules aperiodic CSI report(s) or activates semi-persistent CSI report(s) on PUSCH with no transport block by a 'CSI request' field on a DCI, the number of nominal repetitions is always assumed to be 1, regardless of the value of numberOfRepetitions. When the UE is scheduled to transmit a PUSCH repetition Type B with no transport block and with aperiodic or semi-persistent CSI report(s) by a 'CSI request' field on a DCI, the first nominal repetition is expected to be the same as the first actual repetition. For PUSCH repetition Type B carrying semi-persistent CSI report(s) without a corresponding PDCCH after being activated on PUSCH by a 'CSI request' field on a DCI, if the first nominal repetition is not the same as the first actual repetition, the first nominal repetition is omitted; otherwise, the first nominal repetition is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213]. |
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DCI field on Dynamic Switching

**Proposal 3.6:** 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.,

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| **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 is 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 is time is associated with the first SRS resource set, and the remaining repetitions follow the configured mapping pattern (cyclic or sequential).
* On the number of SRS resource configured in the two SRS resource sets, support the same number of SRS resources.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Support the first three bullets (there seem to be a typo in second and third bullets: “is time” should change to “in time”).  For the last bullet: We think the restriction is not necessary, but if majority companies support the restriction, we can also accept. |
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NCB based PUSCH: number of PT-RS ports

**Proposal 3.7:** For non-codebook based multi-TRP PUSCH repetition, down-selection one of the two alternatives:

* Alt. 1: the actual number of PT-RS ports corresponding to the 1st and 2nd SRS resource sets are the same.
* 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | We think following Rel. 15 procedures can result in Alt2 (since PTRS port depends on SRS resources, which are configured separately). We did not see a strong need for the restriction in Alt1. |
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CG PUSCH: RV mapping

**Proposal 3.8:** 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 can start also from the first transmission occasion and/or any transmission occasions associated with RV=0 for the second TRP, i.e., initial transmission of a transport block may start towards any TRP if the first transmission occasion of the K repetitions is RV = 0 (if configured RV sequence is {0 2 3 1}) or 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} or {0,0,0,0}) .
* 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).

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Support the proposal. |
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CG PUSCH: Configuration details

**Proposal 3.9-1:** 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.

**Proposal 3.9-2**: 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*’).

**Proposal 3.9-3**: 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **QC** | Proposal 3.9-1: Support.  Proposal 3.9-2: Support.  Proposal 3.9-3: Support. |
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## 3.3 Additional high priority proposals

If companies wish to bring any additional aspects related to PUSCH during RAN1 #106-e, please comment below.

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| Company | Comments |
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# Reference

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| [R1-2106464](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106464.zip) | Enhancements on multi-TRP for reliability and robustness in Rel-17 | Huawei, HiSilicon |
| [R1-2106542](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106542.zip) | Multi-TRP enhancements for PDCCH, PUCCH and PUSCH | ZTE |
| [R1-2106572](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106572.zip) | Further discussion on Multi-TRP for PDCCH, PUCCH and PUSCH enhancements | vivo |
| [R1-2106641](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106641.zip) | Discussion on Enhancements for PDCCH, PUCCH, and PUSCH | InterDigital, Inc. |
| [R1-2106667](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106667.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Lenovo, Motorola Mobility |
| [R1-2106686](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106686.zip) | Discussion on enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Spreadtrum Communications |
| [R1-2106790](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106790.zip) | Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH | Sony |
| [R1-2106866](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106866.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Samsung |
| [R1-2106936](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106936.zip) | Enhancements on multi-TRP/panel transmission for PDCCH, PUCCH and PUSCH | CATT |
| [R1-2107030](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107030.zip) | Enhancements on Multi-TRP for PDCCH PUCCH and PUSCH | Fujitsu |
| [R1-2107079](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107079.zip) | Multi-TRP/panel for non-PDSCH | FUTUREWEI |
| [R1-2107144](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107144.zip) | Discussion on multi-TRP for PDCCH, PUCCH and PUSCH | NEC |
| [R1-2107204](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107204.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | OPPO |
| [R1-2107293](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107293.zip) | Discussion on enhancements on multi-TRP for uplink channels | FGI, Asia Pacific Telecom |
| [R1-2107324](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107324.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Qualcomm Incorporated |
| [R1-2107391](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107391.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | CMCC |
| [R1-2107465](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107465.zip) | On multi-TRP enhancements for PDCCH and PUSCH | Fraunhofer IIS, Fraunhofer HHI |
| [R1-2107486](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107486.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | MediaTek Inc. |
| [R1-2107571](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107571.zip) | Multi-TRP enhancements for PDCCH, PUCCH and PUSCH | Intel Corporation |
| [R1-2107719](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107719.zip) | Views on Rel-17 multi-TRP reliability enhancement | Apple |
| [R1-2107815](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107815.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | LG Electronics |
| [R1-2107839](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107839.zip) | Discussion on MTRP for reliability | NTT DOCOMO, INC. |
| [R1-2107894](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107894.zip) | Enhancements on Multi-TRP for PDCCH, PUSCH and PUCCH | Xiaomi |
| [R1-2108020](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108020.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Convida Wireless |
| [R1-2108053](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108053.zip) | Enhancements for Multi-TRP URLLC schemes | Nokia, Nokia Shanghai Bell |
| [R1-2108072](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108072.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | TCL Communication Ltd. |
| [R1-2108074](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108074.zip) | On PDCCH, PUCCH and PUSCH enhancements for multi-TRP | Ericsson |
| [R1-2108106](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108106.zip) | Discussion on mTRP PXXCH | ASUSTeK |

# Previous Agreements

## 5.1 PUCCH

### 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.

## 5.2 PUSCH

### 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.