3GPP TSG RAN WG1 #105-e R1-200xxxx

e-Meeting, May 19th – May 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 Power Control: *TPC command* | Please refer FL summaries on RAN1 #104e, and 104-bis-e.  | * Company views are diverging, similar to the last two RAN1 meetings.
* The FL proposal from the last meeting is proposed again with the final round of comments from few objecting companies.
* PUSCH TPC command proposal also included within the same discussion.

See FL proposal 2.1. |
| #2: Default beam for PUSCH  | * When PUCCH resource with the lowest ID having two spatial relation info, selects the one with lower ID : **SS**, **QC**, **DCM**, **ZTE, vivo**, **Lenovo**, **CATT, CMCC, Oppo, Apple**
* PUCCH resource with the lowest ID cannot be activated with two spatial relation info: **QC**, **CAICT**, **Lenovo**, **CATT**
* No issue to define anything in the specs – **E///**
 | We discussed this during the last RAN1 meeting. There is a majority of support for defining UE behaviour in the specs.See FL proposal 2.2 |
| #3: Mapping pattern: number of repetitions = 2 | The two transmission occasions are associated with two TRPs respectively, regardless of the configured beam mapping pattern – **CATT, vivo, Nokia, Mtek** | When the number of repetitions = 2, the sequential mapping (RRC configured) does not allow repetition towards multiple TRPs. This proposal can be generalized with PUSCH discussions. See FL proposal 2.3 |
| #4: Mapping pattern: scheme 1 with Frequency hopping  | * Option 1: (12) **Lenovo, CATT**, **CMCC**, **QC**, **CAICT**, **Fujitsu**, **Apple**, **Xiaomi**, **Convida, LG, E///, SS**
* Option 2**:** (1) **MediaTek**
* Option 3: (8) **HW, IDC, vivo, Spreadtrum**, **OPPO**, **Intel, MediaTek**, **Nokia**
 | The majority supports option 1. See FL proposal 2.4 |
| #5: Scheme 3: working assumption | Confirm the working assumption supporting Scheme 3 – **Vivo,** **Nokia**Non-consecutive sub-slots are used for repetition – **Nokia, Xiaomi** | RAN1 has a pending issue “consecutive” in the following working assumption. **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.This was also discussed in the last meeting, but few concerns raised, such as better to wait for IIoT discussion. With the RAN1 TU allocations, it seems IIoT will only resume sub-slot discussions in the August 2021 meeting and feMIMO have to at least decide on removing brackets (on consecutive) or decide how the non-consecutive sub-slot repetition work. This discussion does not require IIoT inputs. See FL proposal 2.5 |
| #6: Mapping pattern: Other details  | * RAN1 supports configurable beam switching gaps – **IDC, Xiaomi**
* Introduce beam/power switching gap between two PUCCH TDMed repetitions considering panel activation delay - **LG**
* Support dynamic switching between cyclic mapping and sequency mapping based on DCI (with regard to unavailable slots/symbols for uplink transmission) – **Apple, Nokia, APT**
 | Based on the conclusion related to the beam switching gap in the last RAN1 meeting, there was no consensus to define any switching gaps, and no inputs from others to change the opinion in RAN1. Three companies suggest discussing dynamic switching of mapping pattern, and FL have not had a proposal on this before. See FL Question 2.6 |
| #7: Scheme 1/3: Repetition numbers | For Scheme 1: For PUCCH formats 1/3/4: 16 **(CATT, E///**)For PUCCH format 0/2: * larger than 2 (**E///**)
* 4, 8, and 16 (**E///)**
* No new values (**Xiaomi)**

For Scheme 3:  X = 2, 4, 8 – **Nokia** | This was discussed with no agreement last time. Very limited inputs this time. No FL proposal.  |
| #8: Scheme 1/3: Other issues | * TRP specific 'initialCyclicShift' of PUCCH Format 0, 'initialCyclicShift' and 'timeDomainOCC' of PUCCH Format 1, 'dataScramblingIdentityPUSCH' of PUCCH Formats 2, 3 and 4. – **ZTE**
* Support dynamic switching between the different multi-TRP PUCCH schemes. - **Nokia**
 | See FL Question 2.7 and Question 2.8. |
| #9: M-TRP intra slot beam hopping (Scheme 2)  | Support Scheme 2: * Yes: **LG, vivo, ZTE Fujitsu, Xiaomi, ZTE, Huawei**
* No: **Spreadtrum, Covinda**
 | This was discussed in multiple meetings. No consensus even in the last meeting. No FL proposal.  |
| #10: PUCCH grouping | * PUCCH group configured for updating spatial relation info can be utilized to link power control parameter sets to a group of PUCCH resources simultaneously. - **vivo**
* Support PUCCH group based spatial relation update for Rel-17 MTRP PUCCH repetition scheme - **ZTE**
* Support that one PUCCH resource can be configured in two PUCCH Groups which correspond to two beams/TRPs in FR2. - **ZTE**
 | Two companies suggest discussing PUCCH grouping. But minimal inputs even with a FFS item last time. No FL proposal.  |
| #11: Handling of overlapping PUCCHs | Rel-15 collision handling is also applied for M-TRP schemes – **E///**Only the first PUCCH considered when intra-slot PUCCH repetitions overlap with a same PUCCH in multiple sub-slots – **TCL** | FL perspective, these are not essential and can be handled later (if many other companies thinking in the same direction) |

## 2.2 Feature lead Proposals

### Proposal 2.1: Power control TPC

**[Draft for offline] Proposal 2.1:**

* 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).
* 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 both PUCCH beams.
* 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.
* Note1: Per TRP closed-loop power control is only applicable when the “closedLoopIndex” values are not the same for TRPs.
* Note2: UE capability related to the above can be discussed in the UE feature discussions.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **Apple** | **We suggest we list original 4 options and discuss this issue online. We failed to reach consensus from offline discussion in multiple meetings. We still think option 3 is the worst solution compared to other options.**  |
| **MediaTek** | **Support** |
| **QC** | **We generally support the FL proposal. In our view, this is a compromise based on the status of discussions so far.** |

### Proposal 2.2: Default beam for PUSCH

**[Draft for offline] 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** |
| **Apple** | **Support** |
| **MediaTek** | **Do not support. Since multiple PUCCH resources can be configured and it is unusual that all PUCCH resources have two spatial relation info, it suffices that the PUCCH resource with the lowest ID is always activated with one single spatial relation info.** |
| **QC** | **Support. We are also fine with agreeing that UE does not expect the PUCCH resource with the lowest ID to be activated with two spatial relation info.** |

### Proposal 2.3: Number of repetitions equal to two

**[Draft for offline] Proposal 2.3:** 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.

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **Apple** | **We do not know why this proposal is needed. Could proponents clarify the motivation?** |
| **MediaTek** | **Support. @Apple: Without this proposal, sequential mapping applies the same beam to both repetitions and there is no spatial diversity.**  |
| **QC** | **Ok with the proposal as the number of repetitions can be dynamic (for PUSCH) or can be per PUCCH format / resource (for PUCCH) while the mapping pattern is RRC configured and common to all PUCSH / PUCCH transmissions.** |

### Proposal 2.4: Scheme 1 - Frequency hopping and beam mapping

**[Draft for offline] 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 (or power control parameter set).

Please comment on preferred changes to the proposal.

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| **Company** | **Comments** |
| **Apple** | **Support** |
| **MediaTek** | **Do not support. Sequential mapping in combination with inter-slot FH is sufficient. The order of frequency diversity and beam diversity is not essential.** |
| **QC** | **Support. The benefit compared to Options 2/3 have been discussed at length before (early termination benefit with both beam and freq. diversity).** |

### Proposal 2.5: Intra-slot repetition (scheme 3)

**[Draft for offline] Proposal 2.5:** For multi-TRP intra-slot repetition (Scheme 3),

* FFS1: On the support of consecutive or non-consecutive sub-slots, decide one of the following,
	+ Alt.1: Consecutive sub-slots are applicable for any sub-slot configuration.
	+ Alt.2: Non-consecutive sub-slots are applicable only for 2-symbol sub-slot configuration, where one sub-slot can be skipped between PUCCH repetitions towards different TRPs
	+ Alt.3: Non-consecutive sub-slots are applicable for both 2-symbol and 7-symbol sub-slot configuration, where one sub-slot can be skipped between PUCCH repetitions towards different TRPs.
		- Note: two 7-symbol sub-slot repetitions are no longer within a slot.
* FFS2: Confirm the working assumption (*removing brackets on [consecutive] depend on FFS1*).

**Working Assumption**

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.

Please comment on preferred changes to the proposal. Provide inputs on FFS1 and FFS2.

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| **Company** | **Comments** |
| **Apple** | **For FFS1: We suggest to add a Alt as follows:*** **Alt4: Whether to support consecutive or non-consecutive sub-slots are based on UE capability**
 |
| **MediaTek** | **For Alt. 2 and Alt.3, we prefer that one sub-slot can be skipped only when the PUCCH resource is of the same number of symbols as the length of subslot. Since a one-symbol gap is sufficient, there is naturally a gap if one repetition does not use all symbols in a subslot.****With the above revision, we support Alt. 2 and support to confirm the working assumption.** |
| **QC** | **Sub-slot configuration is up to IIoT AI to decide. Furthermore, we concluded in the previous meeting to not introduce gap due to beam switch from RAN1’s perspective. Hence, the sub-slot configuration for single-TRP (to be defined by IIoT) can be directly used for mTRP.** |

### Question 2.6: Dynamic switching of mapping pattern

**Question 2.6:** Please indicate views on supporting dynamic switching of cyclic mapping and sequence mapping (e.g. based on DCI) as suggested by several companies to provide additional flexibility of the mapping pattern. If RAN1 supports this, what should be the best way to support such a feature.

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| **Company** | **Comments** |
| **Apple** | **Support dynamic indication to avoid some non-available slots/symbols for UL transmission**  |
| **MediaTek** | **Do not support. Since multiple PUCCH resources can be configured and one of them can be dynamically indicated by DCI, dynamic switching of beam mapping patterns can already be implicitly supported.** |
| **QC** | **We do not support dynamic switching of mapping pattern. First, the design should be consistent with PDSCH schemes in Rel. 16. Second, this is an over-optimization w/o clear use case or benefit while it impacts the DCI signaling.** |

### Question 2.7: PUCCH format related aspects

**Question 2.7:** Please indicate views on supporting TRP specific parameters such as 'initialCyclicShift' of PUCCH Format 0, 'initialCyclicShift' and 'timeDomainOCC' of PUCCH Format 1, 'dataScramblingIdentityPUSCH' of PUCCH Formats 2, 3 and 4.

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| **Company** | **Comments** |
| **Apple** | **Do not support. We failed to see the necessity, but it increases RRC overhead.** |
| **MediaTek** | **Do not support. Since sufficient coordination between two TRPs is required to support M-TRP PUCCH schemes, these parameters do not need to be TRP specific.** |
| **QC** | **We do not support this. We also did not see the necessity of such enhancements.** |

### Question 2.8: Switching of M-TRP PUCCH schemes

**Question 2.8:** Please indicate the considerations/views on switching of M-TRP PUCCH schemes (Scheme 1 and Scheme 3).

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| **Company** | **Comments** |
| **Apple** | **Different PUCCH resources can be configured with different schemes. The switching can be performed by indicating different PUCCH resources.** |
| **MediaTek** | **For switching of PUCCH schemes, we prefer to directly refer to the design of Rel-17 eIIoT, if any.** |
| **QC** | **If the intention is switching between PUCCH Schemes 1 and 3, such discussions may not be meaningful now as the sob-slot configurations first need to be decided (by IIoT WI).** |

## 2.3 Additional high priority proposals

In this FL summary, I have not included any FL proposals based on certain other directions discussed before and have not had consensus. If companies wish to bring any additional aspects related to PUCCH during RAN1 #105 -e, please comment below.

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| Company | Comments |
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#  Multi-TRP PUSCH transmission

The remaining open issues and company views are summarized below. 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** |
| Power Control: *TPC command*  | Open issue from three meetings. Company views are more or less captured in earlier FL summaries of RAN1 #104-e and #104-bis-e.  | FL views that the same solution as PUCCH can be agreed. Check Proposal 2.1.  |
| #1: Power control: OLPC | If SRS resource indicator is present* Two separate OLPC parameter set indication fields (1-bit DCI per TRP) – **FW, vivo,** **Xiaomi, Spreadtrum, QC, Oppo, Intel, Nokia**
* The existing OLPC set indication bit field is used – **E///, SS**
* A second p0-PUSCH-SetList-r16 is configured **– QC, Oppo, SS** (with a single field)

If SRS resource indicator is not presentSingle OLPC field with bit width of 2 or 3 bits can be supported – **vivo*** According to the service type of transmission, the first bit is used to inform UE which set that P0 is from. The second and third bit is used to select P0 from p0-PUSCH-Set-r16 for PUSCH repetitions towards multiple TRPs respectively - **vivo**
 | Multiple companies provided inputs on OLPC indication per TRP. At least for the case where SRS resource indicator is present, the majority view is that two separate OLPC parameter set indication fields shall be supported. The case of SRS resource indicator not present is not discussed in details. vivo has a proposal on that. See FL proposal 3.1 |
| #2: Power control: PHR reporting | * Option 1: (2) **QC** (actual PHR), E/// (with dynamic TRP swapping)
* Option 2: (8) **Spreadtrum, ZTE, SS**, **Sharp**, **ASUSTeK**, **LG**, **APT, Nokia**
* Option 4: (17) **HW, vivo, IDC, Lenovo, OPPO**, **Apple**, **SS**, **MediaTek**, **Xiaomi**, **Convida**, **Sharp**, **LG**, **APT**, **TCL**, **Nokia, Xiaomi, E///**
* Option 5: (2) **FW, QC** (virtual PHR)

Other suggestions* Triggering condition of PHR should be clarified before agreeing on the enhancement on PHR report – **vivo**
* Triggering events of PHR shall be defined per TRP - **vivo**
* Send LS to RAN2 to ask their opinion on Option 2/Option 4. – **Intel**, **vivo**
* Support to configure the higher layer parameters {'phr-PeriodicTimer', 'phr-ProhibitTimer', 'phr-Tx-PowerFactorChange'} of PHR trigger events as TRP specific – **ZTE**
 | RAN1 should down-select one option in this meeting as per the agreement in RAN1 #104-bis, and the majority supports Option 4. See FL proposal 3.2 |
| #3: Power control: remaining details | Default PC parameters when SRI fields are absent: **vivo, CATT**, **ZTE**, **APT**. **TCL, QC**Details on default PC * A first value in {P0-AlphaSet, the PL-RS corresponded to *sri-PUSCH-PowerControlId* = 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 *sri-PUSCH-PowerControlId* = 1 and closed-loop index *l* = 1} for TRP 2 - **ZTE**
* A first *sri-PUSCH-PowerControlId* = 0 associated with the first SRS resource set and a second *sri-PUSCH-PowerControlId* = 0 associated with the second SRS resource set are configured – **QC**
	+ A first (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 (second) *sri-PUSCH-PowerControlId* = 0 associated with the first (second) SRS resource set – **QC**
* There are some other flavours mentioned by DCM and CATT, but it seems that variants depend on the assumption of *sri-PUSCH-PowerControl.*
 | Several companies discuss the issue of SRI field is not present in DCI format 0\_1 and 0\_2, but two power control parameters are configured corresponding to each SRS resource set. See FL proposal 3.3 |
| #4: PTRS-DMRS association | * Option 1 (4 bits): (5) **Apple**, **MTek (**DCI 0\_1**),** **Xiaomi**, **QC**, **HW (**configurable**)**
* Option 2 (2 bits): (2) **ZTE**, **Qualcomm**
* Option 3 (2 bits): (10) **vivo, CATT, OPPO**, **MediaTek (**DCI format 0\_2**),** **E///**, **LG**, **SS**, **HW (**default**), Intel**, **Nokia**
 | Majority support option 3. See FL proposal 3.4 |
| #5: A-CSI on M-TRP PUSCH repetition  | A-CSI for the case without a TB:* Support: **HW**, **vivo**, **OPPO**, **Intel**, **Ericsson**, **TCL**, **Qualcomm**, **Nokia**

Other relevant details* For multi-TRP PUSCH repetition Type A: multiplexing applied 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. – **QC**
* When A-CSI is reported by two PUSCH repetitions, the CPU should be occupied from the last symbol of PDCCH triggering the CSI report until the last symbol of the second PUSCH repetition carrying the report. - **Apple**
 | A large number of companies support the FFS item on A-CSI on PUSCH without a TB. See FL proposal 3.5.1For Type A, conditions to apply A-CSI multiplexing is proposed by QC. See FL proposal 3.5.2 On the CPU related proposal from Apple, specs says the following, “*An aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol of the scheduled PUSCH carrying the report*”. From FL perspective, RAN1 can make a conclusion to make things clear for M-TRP operation (no spec impact). See FL proposal 3.5.3 |
| #6: Support dynamic switching  | Size of new DCI field * Two bits field – (19) **FW, HW,** **IDC**, **vivo**, **Lenovo**, **ZTE (**three status), **Fraunhofer**, **Xiaomi**, **DCM**, **LG**, **Ericsson**, **TCL**, **QC**, **Apple**, **CAICT**, **Nokia**, **Oppo, Intel, SS**
* 1 Bit field: (5) **Spreadtrum**, **Covinda**, **ASUSTeK**, **APT**, **CMCC**

SRI/TPMI field applied for S-TRP indication* First SRI (for NCB)/TPMI (for CB) field is used when the DCI indicates all repetitions are associated with one SRS resource set – **QC, E///**
* Corresponding SRI (for NCB)/TPMI (for CB) field is used when the DCI indicates all repetitions are associated with one SRS resource set – **Oppo, DCM**

Other details* Associating SRS resource sets and sets of repetitions – **QC, SS (?), Fraunhofer, DCM**
* Discuss also possibilities of reusing one or more entries in SRI and/or TPMI (e.g. when 2 bit filed is not configured) - NEC, **SS**, **CATT, ZTE**
* MAC CE can be introduced to activate the codepoints for the introduced new field to further reduce the overhead – **vivo**
 | Majority support 2-bit field for dynamic switching. Few companies provided details on mapping, and indicating all four combinations (TRP1, TRP2, TRP1-TRP2, TRP2-TRP1) is the way to go. Two companies discuss which SRI/TPMI field to associate when a single TRP is indicated. FL thinks that the first SRI/TPMI can be used without any big issue. Another discussion was on how the SRS resource sets are mapped to combinations of DCI indication (or TRPs). As proposed by few companies, a simple association from SRS resource set ID can be used. See FL proposal 3.6-1 and 3.6-2 |
| #7: NCB based PUSCH: 2nd SRI field | Confirm the WA on the second SRI field: **HW**, **IDC**, **Lenovo**, **OPPO**, **Xiaomi**, **Sharp**, **Ericsson**, **APT**, **Nokia**Set of SRS port number of SRS resource(s) in two SRS resource sets are expected to be same. - **vivo** | Confirming working assumption seems possible. See FL proposal 3.7 |
| #8: CB based PUSCH: 2nd TPMI design | Support PUSCH repetitions transmitting towards multiple TRPs sharing the same TPMI – **vivo, QC*** The presence of the second TPMI field can be separately configured for DCI format 0\_1 and DCI format 0\_2**. – QC**
 | This was discussed before, and companies had different opinions. See question 3.8 |
| #9: M-TRP CG PUSCH: RV mapping  | RV sequence * The first RV for the first PUSCH repetition and a RV offset for the starting RV for the second TRP are configured – **CATT, QC, Intel, Oppo, Nokia**
* Support two RV sequences **– Xiaomi**

Starting RV for transmission * RV sequence is always expected to be mapped starting with 0 onto the first transmission occasion targeting each TRP - **Xiaomi**
* with RV pattern 0231, support initial transmission at the first transmission occasion of TRP 1 or at the first transmission occasion of TRP 2. - **LG**
* 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**
* If startingFromRV0 is set to 'on', for each of the two sets of the transmission occasions associated with different UL beams, the initial transmission of a TB may start at any of transmission occasions with RV=0 - **TCL**

Other a new field can be introduced to indicate the second RV sequence - TCL | Several companies indicated that RV sequence should be configured to be the same for both TRPs. Also, similar to DG-PUSCH an offset may be configured for the second TRP. On the starting RV, TCL and Xiaomi referred to the different modes supported in Rel-16 by *startingFromRV0,* which is controlling CG PUSCH initial transmission start from any transmission with RV0 or always starting with the initial transmission. See FL proposal 3.9.  |
| #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, Nokia**
* For type 1 CG, support the same association rule between PT-RS and DM-RS as in Rel-15/16 – **Oppo, CATT, Nokia**
* 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**
 | Views are diverging, and very few inputs. Based on companies’ inputs, there seems nothing needed to enhance on PT-RS DMRS association where the association rule from Rel-15/16 can also apply for m-TRP operation. See FL proposal 3.10  |
| #11: M-TRP CG PUSCH: other details | CG Type 1* For type 1 CG, support to introduce the second field of 'dmrs-SeqInitialization' in 'rrc-ConfiguredUplinkGrant’. - **ZTE, Intel**
* if the higher layer parameter of rrc-ConfiguredUplinkGrant is not included in ConfiguredGrantConfig, the PL-RS resource index for two TRPs should be determined.- **TCL**

CG type 2* Two default beams can be applied for CG type 2 when it is activated by DCI format 0\_0. **– vivo**
* For type 2 CG based multi-TRP PUSCH repetition: 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. – **QC**

Other * Further enhance power control of CG retransmission: At least PL-RS of the scheduled retransmission shall be indicated by the scheduling DCI instead of reusing the one configured for CG. - **vivo**
 | Different views, but mainly one or two company proposals. On CG Type 1, two companies propose to use different DMRS sequence initialization. But this is not used for DG-PUSCH in multi-TRP, and does not make sense only to introduce for CG PUSCH. RAN1 can come back to this if DG PUSCH uses such an approach. On CG Type 2, QC proposal on how the DCI field applicable for CG PUSCH seems relevant. See FL proposal 3.11.  |
| #12: PUSCH Frequency hopping | * For inter-repetition frequency hopping with PUSCH repetition Type A or Type B, frequency hopping is performed among the repetitions with the same beam when cyclical mapping pattern is configured. – **QC**, **Fujitsu, LG, Lenovo, CATT, E///**
* Support beam mapping per frequency hop when inter-slot frequency hopping is configured – **vivo**
* The two transmission occasions are associated with two TRPs respectively, regardless of the configured beam mapping pattern **– CATT**
 | The majority supports the per TRP inter-repetition FH. See FL proposal 3.12.  |
| #13: 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 that meets Z and Z’ requirement (if applicable) 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**
* Discuss different cases of overlapping PUCCHs/PUSCHs for multi-TRP operation to be further discussed - **APT**
 | Not the most essential feature to finalize the design details. We can come back to this later.  |

## 3.2 Feature lead Proposals

### Proposal 3.1: OLPC set indication

**[Draft for offline] Proposal 3.1:** For indicating per-TRP OLPC set in DCI format 0\_1/0\_2,

* If two SRI fields present in the DCI,
	+ Support a second field (1 bit) for OLPC set indication and a second p0-PUSCH-SetList-r16.
	+ The first and second OLPC field are associated with the repetitions corresponding to first SRI and second SRI field, respectively.
	+ For first and second OLPC fields,
		- if value of the field equals to ‘0’, the UE determine value of P0 from a first P0-PUSCH-AlphaSet 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 the lowest p0-PUSCH-SetID value corresponding to each TRP.
* If the SRI field is not present in the DCI,
	+ Support a single extended field (2 bit or 3 bits as determined by higher layer parameter olpc-ParameterSetDCI-0-1/0-2) for OLPC set indication and a second p0-PUSCH-SetList-r16.
	+ FFS: details on interpretations

Please comment on preferred changes to the proposal. Please provide your views on FFS.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **We do not think the proposal is needed.** **Current 1-bit indicator when 2 SRI fields present can still be used to indicate OLPC for 2 beams. gNB can apply the same principle to configure the 2 OLPC sets for each beam, so that it can be switched at the same time. So no additional DCI overhead is needed.****When SRI is not present in DCI. Current proposal looks problematic, as it introduces additional overhead but the interpretation is FFS. We cannot support additional DCI overhead without clear interpretation.** |
| **MediaTek** | **Do not support. Per-TRP OLPC set indication by DCI is unnecessary.**  |
| **QC** | **Support the proposal for the case of SRI fields present. When SRI fields are not present can be decided later (also depends on the outcome of Proposal 3.3).****From our perspective, proper enhancement cannot be done if the second OLPC set indication field (1bit) is not added in the DCI as gNB cannot separately control power boost or no power boost per TRP in that case. A half-way enhancement (e.g. by only adding a second RRC w/o adding the corresponding DCI field) is not a good way in our view especially given the fact that the two TRPs see different interference (from other eMBB UEs).** |

### Proposal 3.2: PHR reporting

**[Draft for offline] Proposal 3.2:** For PHR reporting related to M-TRP PUSCH repetition, option 4 is supported,

* Option 4: Calculate two PHRs, each associated with a first PUSCH occasion to each TRP, and report two PHRs
* FFS1: Required changes to triggering conditions including the required higher layer parameters (e.g.,'phr-PeriodicTimer', 'phr-ProhibitTimer', 'phr-Tx-PowerFactorChange' as TRP specific).
* FFS2: Support extensions to both single-cell PHR MAC CE and multi-cell PHR MAC CE
* FFS3: Report P-MPR and MPE per TRP within the same MAC-CE extension.
* FFS4: Send LS to RAN2 as the design details are mainly relevant to RAN2.

Please comment on preferred changes to the proposal. Select your preference for FFS.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Suuport** |
| **MediaTek** | **Support** |
| **QC** | **Do not support. Option 4 has issues wrt causality of PHR report. In existing spec, PHR-MAC-CE does not include “actual PHR” for future slots. For example, for the case of UL CA, only PUSCHs overlapping in the slot of the PUSCH that carries the MAC-CE are considered.** **This is because if PHR for a PUSCH in the future is reported, the scheduling condition for other CCs are not know, and hence, PHR value does not reflect the power allocation on those CCs (which impact the PHR of the target CC).** **In addition, Option 4 results in many RAN2 changes including MAC-CE change, triggering condition, introduction of additional timers (if the intention is per-TRP PHR). We do not think there is enough TU in RAN2 for such enhancements.****In our view, Option 1 is the simplest solution, keeps the actual PHR reporting causal (as in current spec), and allows for alternating between the two TRPs for UL CA as well as in the absence of UL CA when dynamic switching of TRP order is allowed.**  |

### Proposal 3.3: Default PC parameters

**[Draft for offline] Proposal 3.3:** 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.

* 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 signalling link *sri-PUSCH-PowerControl with* two SRS resource sets is up to RAN2.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Support the main-bullet only.** **In our view, the default values should be selected from the first value from corresponding list configured by RRC, e.g. the first PL-RS configured in corresponding PL-RS list, which is like current apporach for default power control parameters. It is not good to bind default values with SRI, since there may be no SRI when unified TCI is enabled.**  |
| **MediaTek** | **Support** |
| **QC** | **Support the proposal.** **We should avoid piecemeal rules in this case (one set of default rules for P0 and alpha, another set of rules for PL-RS, yet a different set of rules for closed loop index). Otherwise, the spec will become unreadable.**  |

### Proposal 3.4: PT-RS DMRS association

**[Draft for offline] Proposal 3.4:** For single DCI based M-TRP PUSCH Type B repetition, the indication of PTRS-DMRS association for maxRank > 2 is supported by the following option,

* 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.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **From performance perspective, we think option 1 is the best. Some more discussion is needed.** |
| **MediaTek** | **We can support this proposal.** |
| **QC** | **We can support either Option 1 or Option 2, but we do not see Option 3 as a valid / complete solution. Either we support more than 2 layers or not. If we support, the PTRS-DMRS association rule should be also properly designed.**  |

### Proposal 3.5: A-CSI on PUSCH

**[Draft for offline] Proposal 3.5.1:** 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).

**[Draft for offline] Proposal 3.5.2:** 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.

**[Draft for offline] Conclusion 3.5.3:** For s-DCI based multi-TRP PUSCH repetition Type A and B, when A-CSI is reported by two PUSCH repetitions, an aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol of the scheduled PUSCH carrying the report (here, the last symbol of the scheduled PUSCH refer to the last symbol of the second PUSCH repetition carrying the report).

* No spec impact to clarify this further.

Please comment on preferred changes to the proposals and conclusion.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **For proposal 3.5.1, we suggest to add bullets as follows*** **The scheduling offset for the first A-CSI should meet the Z and Z’ requirement**

**Support proposal 3.5.2.** **For conclusion 3.5.3, we are ok to make it as a conclusion, but isn’t it better to change spec to make it clear?** |
| **MediaTek** | **Support** |
| **QC** | **For Proposal 3.5.1 and 3.5.2: Support.** **For conclusion 3.5.3: Rel. 15 rule itself may first require a clarification. The spec says “An aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol of the scheduled PUSCH carrying the report.” So, it seems that the proper interpretation of Rel. 15 is that CPU occupation duration is until the last symbol of PUSCH (which means that in the case of repetition, it would be the last symbol of the last repetition). This is because spec does not mention “PUSCH repetition”, and the “carrying the report” refers to the PUSCH (which includes all repetitions).** |

### Proposal 3.6: Dynamic Switching Field

**[Draft for offline] Proposal 3.6-1:** 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

**[Draft for offline] Proposal 3.6-2:** For the new field in the DCI for dynamic switching,

* 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 set2nd 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: 2nd SRS resource set2nd SRI/TPMI field: 1st SRS resource set | 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.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Support 3.6-1****Support 3.6-2** |
| **MediaTek** | **Support** |
| **QC** | **Support both proposals, but is there a need to clarify “first/second SRS resource sets”? For example, when two SRS resource sets with usage set to codebook are configured, there needs to be a clear rule as to which one is “first” and which one is “second”** |

### Proposal 3.7: Second SRI for NCB-PUSCH

**[Draft for offline] Proposal 3.7:** Confirm the following,

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.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Support** |
| **MediaTek** | **Support** |
| **QC** | **Ok.** |

### Question 3.8: Second TPMI field for CB-PUSCH

**Question 3.8:** Please indicate your views on supporting PUSCH repetitions transmitting towards multiple TRPs sharing the same TPMI (Here, the presence of the second TPMI field can be separately configured for DCI format 0\_1 and DCI format 0\_2).

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **We failed to see spec impact** |
| **MediaTek** | **If one of the TRPs cannot use a good TPMI, the gain from M-TRP can be very limited or even worse than single-TRP, especially when the TRP with good TPMI is blocked. We do not support TPMI sharing.** |
| **QC** | **Support the proposal as the overhead of the second TPMI can be large (5bits). We can still have mTRP PUSCH (two beams / two sets of PC params) but with a shared TPMI.** |

### Proposal 3.9: CG PUSCH – RV mapping

**[Draft for offline] Proposal 3.9:** For RV mapping of type 1 or type 2 CG based multi-TRP PUSCH repetition,

* The configured RV sequence (via “*repK-RV*”) is applied separately for PUSCH repetitions corresponding to the first TRP and the second TRP with a possibility of configuring an RV offset for the starting RV corresponding to the second TRP (similar to the case of dynamic multi-TRP PUSCH repetition).
* FFS1: How the *startingFromRV0* is associated with the initial transmission of a TB corresponding to each TRP.

Please comment on preferred changes to the proposal. FFS1 needs more inputs.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Do not support to configure an RV offset for the second TRP. Such RV offset is a kind of fixed configuration, since it is based on RRC. So we do not see any benefit to configure the RV offset.** |
| **MediaTek** | **Support** |
| **QC** | **Support the proposal to unify the design with the DG case. In addition, if the RV offset is not introduced, then additional repK-RV sequences need to be introduced for the second TRP (with larger RRC overhead, and unnecessary discussions of the choice of the second sequence).** |

### Proposal 3.10: CG PUSCH – PTRS DMRS association

**[Draft for offline] 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

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **As we proposed, PT-RS to DMRS port association cycling could provide better performance. The associated DMRS port index for a PT-RS port should be selected based on the repetition index.** **This proposal 3.10 should be the worst from performance perspective.** |
| **MediaTek** | **Support** |
| **QC** | **Support. Anyway, the current rule in the spec is enough (no enhancement is needed; hence, the discussions can be also skipped).** |

### Proposal 3.11: CG PUSCH remaining details

**[Draft for offline] Proposal 3.11:** 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.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **We think it is better to use the same approach as DG-PUSCH, so that the power control parameters are associated with indicated SRIs in activating DCI** |
| **MediaTek** | **Support** |
| **QC** | **Support.** |

### Proposal 3.12: FH and beam mapping for PUSCH

**[Draft for offline] Proposal 3.12:** For inter-repetition frequency hopping with PUSCH repetition Type A or Type B, frequency hopping is performed among the repetitions associated with the same TRP when the cyclical mapping pattern is configured.

Please comment on preferred changes to the proposal.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **Apple** | **Suggest removing “when the cyclical mapping pattern is configured”** |
| **MediaTek** | **Do not support. Sequential mapping in combination with inter-repetition FH is sufficient. The order of frequency diversity and beam diversity is not essential.** |
| **QC** | **Support the proposal. This proposal may also be considered together with Proposal 2.4 (for PUCCH)** |

##  3.3 Additional high priority proposals

In this FL summary, I have not included any FL proposals based on certain other directions that were discussed before and have not had consensus or progress. If companies wish to bring any additional aspects related to PUSCH during RAN1 #105-e, please comment below.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | We suggest to discuss the issue on P/SP-CSI report on mTRP PUSCH |
|  |  |

# Reference

|  |  |  |
| --- | --- | --- |
| [R1-2104201](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104201.zip%22%20%5Ct%20%22_parent) | Multi-TRP/panel for non-PDSCH | FUTUREWEI |
| [R1-2104267](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104267.zip) | Enhancements on multi-TRP for reliability and robustness in Rel-17 | Huawei, HiSilicon |
| [R1-2104293](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104293.zip) | Multi-TRP Enhancements for PUCCH and PUSCH | InterDigital, Inc. |
| [R1-2104344](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104344.zip) | Further discussion on Multi-TRP for PUCCH and PUSCH enhancements | vivo |
| [R1-2104405](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104405.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Lenovo, Motorola Mobility |
| [R1-2104412](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104412.zip) | Discussion on enhancements on Multi-TRP for PUCCH and PUSCH | Spreadtrum Communications |
| [R1-2104485](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104485.zip) | Enhancements on PUCCH and PUSCH | CATT |
| [R1-2104586](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104586.zip) | Multi-TRP enhancements for PUCCH and PUSCH | ZTE |
| [R1-2104600](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104600.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | CMCC |
| [R1-2104655](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104655.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Qualcomm Incorporated |
| [R1-2104733](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104733.zip) | Enhancements on Multi-TRP based enhancement for PUCCH and PUSCH | OPPO |
| [R1-2104841](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104841.zip) | Enhancements on Multi-TRP for uplink channels | CAICT |
| [R1-2104889](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104889.zip) | Multi-TRP enhancements for PUCCH and PUSCH | Intel Corporation |
| [R1-2104945](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104945.zip) | Multi-TRP enhancements for PUCCH and PUSCH | Intel Corporation |
| [R1-2104946](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2104946.zip) | Multi-TRP enhancements for PUCCH and PUSCH | Intel Corporation |
| [R1-2105002](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105002.zip) | Multi-TRP enhancements for PUCCH and PUSCH | Intel Corporation |
| [R1-2105003](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105003.zip) | Multi-TRP enhancements for PUCCH and PUSCH | Intel Corporation |
| [R1-2105059](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105059.zip) | Enhancements on Multi-TRP for PDCCH PUCCH and PUSCH | Fujitsu |
| [R1-2105088](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105088.zip) | Views on Rel-17 multi-TRP reliability enhancement | Apple |
| [R1-2105152](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105152.zip) | Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH | Sony |
| [R1-2105247](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105247.zip) | Discussion on multi-TRP for PUCCH and PUSCH | NEC |
| [R1-2105274](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105274.zip) | Enhancements for Multi-TRP URLLC schemes | Nokia, Nokia Shanghai Bell |
| [R1-2105292](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105292.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | Samsung |
| [R1-2105350](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105350.zip) | On multi-TRP enhancements for PUSCH | Fraunhofer IIS, Fraunhofer HHI |
| [R1-2105354](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105354.zip) | Enhancements on Multi-TRP for PUCCH and PUSCH | MediaTek Inc. |
| [R1-2105541](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105541.zip) | Enhancements on Multi-TRP for PUSCH and PUCCH | Xiaomi |
| [R1-2105589](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105589.zip) | Enhancements on Multi-TRP for PUCCH and PUSCH | Convida Wireless |
| [R1-2105629](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105629.zip) | Enhancements on Multi-TRP for PUSCH | Sharp |
| [R1-2105684](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105684.zip) | Discussion on MTRP for reliability | NTT DOCOMO, INC. |
| [R1-2105731](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105731.zip) | Discussion on mTRP PUSCH | ASUSTeK |
| [R1-2105780](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105780.zip) | Enhancements on Multi-TRP for PUCCH and PUSCH | LG Electronics |
| [R1-2105808](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105808.zip) | On PUCCH and PUSCH enhancements for multi-TRP | Ericsson |
| [R1-2105817](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105817.zip) | Discussion on enhancements for Multi-TRP for uplink channels | Asia Pacific Telecom, FGI |
| [R1-2105837](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105837.zip) | Enhancements on Multi-TRP for PUCCH and PUSCH | TCL Communication Ltd. |

# 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 RBPUCCH Format 3: 4 and 8 symbols, 1 RBOther 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 | TDMDetails 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 1DM-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 | TDMDetails 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.

## 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,

* 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*'.