3GPP TSG RAN WG1 #104-e R1-200xxxx

e-Meeting, January 25th – February 05th, 2021

**Agenda item: 8.1.2.1**

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

**Title: Summary of Multi-TRP for PUCCH and PUSCH**

**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 and several FL proposals are listed in section 2-4 (section 4 to be added later). For additional information, Section 5 contains all the proposals submitted by company contributions. The agreements reached in previous RAN1 meetings are provided in Section 7.

# Multi-TRP PUCCH transmission

The first sub-section below summarizes company proposals, the second sub-section provide FL proposals, and the third sub-section allows companies to add further comments on any missing proposals which companies think high-priority.

## 2.1 Summary of contributions

In the last meeting, several agreements were made related to M-TRP PUCCH transmissions. The remaining issues which are highlighted by company contributions are summarized below.

**Table 1: Summary: Supported M-TRP PUCCH schemes**

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| **Issue** | **Summary from Tdocs** | **Moderator comments** |
| 1. M-TRP inter slot repetition (Scheme 1): Number of repetitions | Number of repetitions   * **Support 2/4/8** (same as Rel-15): FW, Oppo * **Other values**: CATT/Xiaomi (16)   Support dynamic indication   * **Yes**: InterDigital, Lenovo, QC, ZTE, Nokia, MTek, Spreadtrum, TCL, Xiaomi * **No**: FW, Apple (not in feMIMO)   Method of dynamic indication   * **Associated to the PUCCH resource**: QC, Spreadtrum, Xiaomi | On the number of repetitions, starting with Rel-15 values seems reasonable.  There is good support for the dynamic indication of the number of PUCCH repetition. Based on FL reading,   * The method of dynamic indication may not increase DCI size. * Other WIs will not decide on the dynamic indication for M-TRP (based on RAN guidance). * Coverage enhancement WI has an objective on specifying dynamic indication, feMIMO could refer to the same method of dynamic indication for M-TRP PUCCH repetition.   Please check FL proposal 2.1 |
| 1. Scheme 1: PUCCH format 0/2 | Support PUCCH format 0/2 for Scheme 1   * **Yes**: Oppo, Lenovo, QC, Nokia, Intel, CMCC, Xiaomi, SS, Apple, DCM, Spreadtrum * **No**: FW, HW | Majority of companies support PUCCH format 0/2 for scheme 1.  Please check FL proposal 2.2 |
| 1. Support of M-TRP intra slot beam hopping (Scheme 2) and M-TRP intra-slot repetition (Scheme 3) | * **Support only Scheme 3**: Oppo, Lenovo, CATT, Nokia, Intel, Spreadtrum, CMCC, SS, E///, TCL * **Support both Scheme 2 & 3**: HW, FW, Vivo, Fujitsu, Xiaomi, DCM, QC/MTek/LG (Support Scheme 3 if supported by Rel-17 eIIoT) | There is majority support for Scheme 3. Only three companies prefer intra-slot repetition scenario to be agreed first in eIIoT.  From FL perspective, there is good support for Scheme 3. Based on RAN guidance, there is no restriction to support Scheme3 only considering M-TRP operation.  Check FL proposal 2.3 |
| 1. PUCCH formats for Scheme 2/3 (if supported): | PUCCH formats for Scheme 3,   * **PUCCH format 0/2**: Lenovo, QC, CATT, Nokia, Intel, Spreadtrum, CMCC, Xiaomi, DCM, E///, Oppo * **All formats**: Spreadtrum, CMCC, Xiaomi, DCM, E/// * **PUCCH format 1/3/4:** FW   PUCCH formats for Scheme 2  **All Formats**: MTek, QC, DCM | Around 11 companies support at least PUCCH format 0 and 2 for the scheme 3.  Check FL proposal 2.3 |
| 1. Power Control: TPC command | * **Option 1:** (4) Oppo, Lenovo, QC, Intel, SS * **Option 2**: (3) HW, APT, SS * **Option 3**: (12) Lenovo, CATT, Nokia, MTek, LG, Intel, NEC, CMCC, Xiaomi, Covinda, DCM, E/// * **Option 4**: (10) FW, Oppo, Lenovo, QC, CATT, Vivo, LG, Spreadtrum, Apple, E///   Use the same solution in PUSCH/PUCCH – Intel, NEC, SS | Both option 3 and 4 seems to be having good support. Down selection during the RAN1 #104e can be done for option 3 and 4.  Several companies also highlighted that the same solution should be used for PUSCH, that makes sense.  Check FL proposal 2.4 |
| 1. Power control: FR1 remaining details | **Support two sets of power control parameters for FR1:** FW, Oppo, Lenovo, ZTE, CATT, Nokia, SS, Apple, DCM  Details of configuration/indication and association to a PUCCH resource:   * RRC configured two sets: CATT, FW, Lenovo * Activated using the same RRC/MAC-CE of spatial relation info: QC, SS (alt.2) * A new MAC-CE to update power control parameters for PUCCH resource (or list): Apple * Enhance the default PUCCH power control without providing spatial relation info: SS (alt.1), Oppo * Associate the PUCCH resource with the 1st and 2nd lowest ID PC parameters – LG | There is good support for extending the power control parameters for FR1 M-TRP operation.  Also, there are some design details, which we could also discuss further during the meeting.  Check FL proposal 2.5 |
| 1. Frequency hopping for Scheme 1 | **FH applied per beam (scheme 1):** Lenovo, QC | There is a working assumption on how repetitions are mapped to beams. By configuring a suitable mapping pattern, there seems to be a possibility of controlling that the beam hopping applies per beam or not.  Check FL proposal 2.6 |
| 1. Beam/power control parameter set mapping | Confirm working assumption: Intel, CMCC, Xiaomi  Study impact due to flexible DL symbols: LG  Configure beam mapping pattern like indication for indicating the power control parameter set: DCM, Lenovo | There are few inputs on beam mapping as RAN1 already has a working assumption on how beams shall be mapped considering FR2 and Scheme 1.  RAN1 shall make agreements on beam mapping for Scheme 3 (if supported) and power control parameter set mapping for FR1.  Check FL proposal 2.7 |
| 1. Switching S-TRP and M-TRP PUCCH repetition scheme(s) | **Support dynamic switch**: Nokia, Intel, Spreadtrum, DCM  Details of switching  **Associating a PUCCH resource with one or two spatial-relation-info**: Intel | Several companies provided details. From FL perspective, similar to Rel-16 URLLC schemes, RAN1 can discuss supporting dynamic switching of S-TRP and M-TRP modes.  Check FL proposal 2.8 |
| 1. Activating multiple spatial relation info per PUCCH resource | **PUCCH grouping for S-TRP and M-TRP**: Intel, ZTE | MAC-CE design details are up to RAN2.  PUCCH grouping was discussed in the past, and FL sees that as a secondary issue. No FL proposal. |
| 1. Multiple PUCCH resources | Multiple PUCCH resources:   * **Yes**: FW, InterDigital, Lenovo, LG, SS, TCL * **No**: Oppo, Vivo, DCM | This was discussed heavily in the last RAN1 meeting from FL perspective, and the majority was not supporting multiple PUSCH resources. RAN1 shall finalize the single PUCCH resource scenario as it is already agreed. No FL proposal is made. |

## 2.2 FL proposals

**[Draft for offline] Proposal 2.1:** For M-TRP PUCCH scheme 1,

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

**[Draft for offline] Proposal 2.2:** For M-TRP PUCCH scheme 1,

* Values for the total number of repetitions at least contain values 2, 4, and 8.
* When using Rel-15 PUCCH repetition framework, the 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).
* Support the dynamic indication of the number of repetitions
  + FFS#1: Defining the exact method of dynamic indication
    - Alt.1: Discuss the solution in Rel-17 feMIMO
    - Alt.2: Refer the design details to Rel-17 coverage enhancement.

Please comment preferred changes on the proposal below. Also, provide your preference for FFS.

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| **Company** | **Comments** |
| NTT Docomo | We support the proposal.  For the FFS part, we prefer alt.2 so that we have a unified design for S-TRP and M-TRP. |
| MediaTek | We do not support Proposal 2.1. Since short PUCCH formats can be easily repeated within a slot, we do not see the need to support PUCCH formats 0 and 2 for inter-slot repetition. Instead, we prefer to have intra-slot beam hopping to shorten the latency. We provide more details of intra-slot beam hopping in additional high priority proposals.  We Support Proposal 2.2. For dynamic indication, we prefer Alt. 2 as there seems no particular issue to be considered from MIMO’s perspective. |
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**[Draft for offline] Proposal 2.3:** For PUCCH reliability enhancement, support multi-TRP intra-slot repetition (Scheme 3) at least for PUCCH formats 0/2.

* The same PUCCH resource carrying UCI is repeated for X consecutive sub-slots within a slot.
  + For 7 symbol sub-slot configuration, X = 2
  + FFS1: values of X for 2 symbol sub-slot configuration
* FFS2: Scheme 3 is also supported across multiple slots
  + Alt.1: extended for multiple slots
  + Alt.2: defined only within a slot
* FFS3: PUCCH formats 1/3/4 are also supported for Scheme 3.
  + Alt.1: support format 1/3/4
  + Alt.2: do not support format 1/3/4

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

Please comment preferred changes below. Also, highlight your preferences for FFS points.

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| **Company** | **Comments** |
| NTT Docomo | We support the proposal.  For FFS1, we think the number of intra-slot repetition can be configurable similar as inter-slot repetition.  For FFS2, we support alt.1.  For FFS3, we are fine with alt.1, but we would like to note that PUCCH format 1/3/4 can only be supported when the number of symbols is <=7. |
| MediaTek | Support Proposal 2.3.  FFS1: X = 2, 4, 8  FFS2: Alt. 1, but we prefer it listed as UE capability.  FFS3: Alt. 1 |
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**[Draft for offline] Proposal 2.4:** Select one from the following options to support per TRP closed-loop power control for PUCCH/PUSCH,

* 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.

Please comment preferred changes below. Also, highlight your preferences for option 3 and 4.

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| **Company** | **Comments** |
| NTT Docomo | We support the proposal and prefer option3.  For option4, we suggest more clarification on whether the DCI overhead is expected to be increased with option4, which is beneficial for the comparison between option3 and option4. |
| MediaTek | Our first preference is Option 3, but Option 4 is also fine. |
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**[Draft for offline] Proposal 2.5:** To support per TRP power control for multi-TRP PUCCH schemes in FR1,

* Two sets of power control parameters are configured via RRC, 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.

Please comment preferred changes on the proposal below. Also, provide your preference for FFS.

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| **Company** | **Comments** |
| NTT Docomo | We support the proposal. |
| MediaTek | Support |
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**[Draft for offline] Proposal 2.6:** For inter-slot frequency hopping in Scheme 1, further discuss the following alternatives,

* Alt.1: frequency hopping is performed among the repetitions with the same beam
* Alt.2: frequency hopping is performed on slot level (as in Rel-15).

Note: Outcome of Alt.1 can also be achieved by Alt.2 when using the sequential beam mapping.

Please comment preferred changes on the proposal below. Mention the support for Alt. 1 or 2.

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| **Company** | **Comments** |
| NTT Docomo | We think this issue can be discussed after we have agreed on the beam mapping pattern. |
| MediaTek | Support Alt. 1. Alt. 2 cannot exploit all diversity gains when using cyclic beam mapping unless the hopping pattern is modified. |
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**[Draft for offline] Proposal 2.7:** 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.

Please comment preferred changes on the proposal below.

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| **Company** | **Comments** |
| NTT Docomo | We support this proposal in general.  But we think the discussion for FR1 may depend on the progress of proposal 2.5 and can be discussed later. Or we add in the first bullet “if two sets of power control parameters configured via RRC is supported”. |
| MediaTek | Support |
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**[Draft for offline] Proposal 2.8:** For Multi-TRP Scheme 1, support dynamic switching between multi-TRP PUCCH scheme and single-TRP PUCCH transmission by associating,

* a PUCCH resource with one or two spatial-relation-info and PRI bit-field indicating a PUCCH resource (for FR2).
* a PUCCH resource with one or two power control parameter sets and PRI bit-field indicating a PUCCH resource (for FR1)

FFS: support of dynamic switching for Scheme 2/3 (if the schemes supported)

Please comment preferred changes on the proposal below.

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| **Company** | **Comments** |
| NTT Docomo | We support the proposal in general.  Similar as we comment in proposal 2.7, we think the discussion for FR1 may depend on the progress of proposal 2.5 and can be discussed later. Or we add in the second bullet “if two sets of power control parameters configured via RRC is supported”. |
| MediaTek | Support |
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## 2.3 Additional high priority proposals

In this FL summary, we have not included any FL proposals based on certain other directions suggested by one or two companies. Such proposals are not considered if that is not critical for the basic design framework or can be discussed in a later stage once the basic framework is agreed. Please see the full list of company contribution proposals in Section 5. If companies wish to bring any additional aspects related to PUCCH during RAN1 #104-e, please comment below.

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# [Multi-TRP PUSCH Transmission ] % Will be updated

The first sub-section below summarizes company proposals, the second sub-section provide FL proposals, and third allows companies to add further comments on any missing proposals which companies think high priority.

## 3.1 [Summary of contributions]

In the last meeting, several agreements were made related to M-TRP PUSCH transmissions. The remaining issues which are highlighted by company contributions are summarized below.

**Table 1: Summary: Supported M-TRP PUSCH schemes**

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| **Issue** | **Summary from Tdocs** | **Moderator comments** |
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## 3.2 [FL proposals]

## 3.3 [Additional high priority proposals]

In this FL summary, we have not included any FL proposals based on certain other directions suggested by one or two companies. Such proposals are not considered if that is not critical for the basic design framework or can be discussed in a later stage once the basic framework is agreed. Please see the full list of company contribution proposals in Section 5. If companies wish to bring any additional aspects related to PUSCH during RAN1 #104-e, please comment below.

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| Company | Comments |
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# [Second Phase]

# Summary of Technical proposals

## 5.1 Proposals on PUCCH

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| Company | Proposals |
| FutureWei | Proposal 2: For M-TRP PUCCH inter-slot repetition and intra-slot repetition (if supported), support the same PUCCH repetition numbers to each TRP as the existing nrofSlots repetition numbers.  Proposal 3: For M-TRP PUCCH transmission schemes, also support at least Scheme 3 intra-slot repetition.  Proposal 4: For M-TRP PUCCH inter-slot repetition and intra-slot repetition (if supported), focus on PUCCH formats 1, 3, and 4.  Proposal 5: For M-TRP PUCCH inter-slot repetition and intra-slot repetition (if supported), deprioritize dynamic indication of repetition number.  Proposal 6: To enable TDMed PUCCH transmissions with different multiple spatial relation info, also support multiple separate PUCCH resources, each associated with one spatial relation info.  Proposal 7: For M-TRP PUCCH power control, configure multiple separate sets of PUCCH power control parameters, each set associated with one TRP in RRC configuration and including TRP-specific open-loop parameters, closed-loop parameters, and spatial relation info and/or pathloss RS, and   * Support 2 TPC fields in DCI formats 1\_1, 1\_2, and 2\_2, each TPC field is configured for one TRP; * Reword to when the “closedLoopIndex” values associated with the two PUCCH spatial relation info’s are for different closed-loops. |
| InterDigital | Proposal 6: Support multiple PUCCH resources for PUCCH repetitions.  Proposal 7: Support dynamic indication of PUCCH mapping patterns and number of repetitions. |
| Huawei | Proposal 21: For PUCCH enhancement, support both Schemes 2 and 3.  Proposal 22: For per TRP closed-loop power control for PUCCH transmission, support Option 2. |
| Vivo | P1: Support Scheme 3, MTRP intra-slot PUCCH repetition, based on sub-slot configuration.  P2: Support Scheme 2, MTRP intra-slot PUCCH beam hopping, by applying the symbol pattern and DMRS pattern of intra-slot frequency hops.  P3: Use of multiple PUCCH resources for MTRP TDM-ed PUCCH transmission schemes is not supported.  P4: Support same PUCCH resource for PUCCH repetition with two spatial relations configured by higher layer signaling or by MAC CE activation.  P5: Support a single TPC field (Option 4) in DCI formats 0\_1 / 0\_2 used to indicate two TPC values. |
| ZTE | Proposal 3-1: One PUCCH resource can be included in two PUCCH Groups correspond to two beams.  Proposal 3-2: One reserved bit in the existing “Enhanced PUCCH Spatial Relation Activation/Deactivation MAC CE” can be used to indicate which one of PUCCH Groups with the same PUCCH resource should be updated.  Proposal 3-3: For separate power control parameters of multi-TRP PUCCH enhancements in FR1, two sets of power control parameters can be configured by RRC signalling where each set has a dedicated value of p0, alpha, pathloss RS ID and a closed loop index.   * One PUCCH resource can be linked to one or both of the two sets of power control parameters.   Proposal 3-4: Support dynamical indication of the number of PUCCH repetitions. |
| Fujitsu | Proposal 4: For PUCCH resource determination for HARQ-ACK when the corresponding PUCCH resource set has a size larger than eight, Alt 2 is preferred:   * Starting CCE index and number of CCEs in the CORESET of one of the linked PDCCH candidates is applied.   Proposal 5: For the TDMed PUCCH schemes for multi-TRP enhancement, support both intra-slot beam hopping (scheme 2) and intra-slot repetition (Scheme 3). |
| TCL communications | Proposal 4: DCI and MAC CE can be feasible methods to dynamically indicate the number of PUCCH repetitions.  Proposal 5: For the support of two PUCCH spatial relations with a single PUCCH resource, the existing PUCCH spatial relation activation MAC CE can be enhanced.  Proposal 6: For configuration/activation of multiple PUCCH spatial relation info, multiple PUCCH resources for PUCCH transmission should be supported.  Proposal 7: For the intra-slot PUCCH transmission schemes, at least Scheme 3 is supported to reduce the feedback latency and improve the reliability.  Proposal 8: For the starting symbol of intra-slot PUCCH repetitions, the reference point for each repetition should be studied.  Proposal 9: Regarding the reference point for the starting symbol of the second and the remaining repetitions, the end of the last repetition or the beginning of a dedicated symbol can be regarded as the reference point.  Proposal 10: If multiple PUCCHs of intra-slot PUCCH repetitions overlap with a same PUCCH in multiple sub-slots, only the PUCCH with an earlier starting symbol is taken into account when compared with other PUCCH in the starting symbol. |
| MediaTek | Proposal 9: Encoding/rate matching should be based on one repetition for intra-slot repetition and one beam hop for intra-slot beam hopping, if supported.  Proposal 10: Multi-TRP intra-slot beam hopping is supported for all PUCCH formats.   * FFS Required guard period for beam switching   Proposal 11: Multi-TRP intra-slot repetition for PUCCH is supported if and only if sub-slot based PUCCH repetition is agreed in R17 URLLC/IIoT WI.  Proposal 12: Option 3, i.e., a second TPC field is added in DCI formats 1\_1 / 1\_2, is supported for per TRP closed-loop power control for PUCCH.  Proposal 13: Support dynamic indication of number of PUCCH repetitions, at least for inter-slot repetition. |
| CATT | Proposal 17: Multi-TRP intra-slot repetition can be applied to further improve the reliability of PUCCH format 0/2.  Proposal 18: For separate MTRP PUCCH power control, option 3 or 4 can be chosen.   * 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.   Proposal 19: For separate MTRP PUCCH close-loop power control in FR1, two sets of p0-Sets, pathlossReferenceRSs and twoPUCCH-AdjustmentStates can be configured.  Proposal 20: More than 8 repetitions, e.g. 16 repetitions, towards two TRPs can be supported to further improve PUCCH reliability. |
| CMCC | Proposal 5: Support Multi-TRP intra-slot PUCCH repetition (Scheme 3).  Proposal 6: Support all the PUCCH formats for Multi-TRP inter-slot and intra-slot repetition.  Proposal 7: Support adding a second TPC field in DCI formats 1\_1 / 1\_2 (Option 3) for Multi-TRP PUCCH power control enhancement.  Proposal 8: Both cyclical mapping and sequential mapping could be considered for PUCCH beam mapping pattern to PUCCH repetitions. |
| Samsung | Proposal 8. Support multi-TRP based PUCCH/PUSCH repetition by using single-DCI based framework as a starting point.  Proposal 9. Support the use of multiple PUCCH resources for multi-TRP based PUCCH repetition.  Proposal 10. Support short PUCCH format for multi-TRP based repetition.  Proposal 11. Support intra-slot level repetition for multi-TRP based PUCCH repetition   * Introduce symbol level offset between PUCCH repetitions with power/beam changes   Proposal 12. For PUCCH enhancements in FR1, it is enough to support separate PUCCH power control parameters for PUCCH repetition into different TRP and the following alternatives can be considered for separate PUCCH power control per TRP:   * Alt.1: Enhance the default PUCCH power control without providing PUCCH-SpatialRelationInfo * Alt.2: Introduce PUCCH-SpatialRelationInfo to support separate PUCCH power control parameters for different TRP in FR1   Proposal 13. Prefer Option. 1 or Option. 2 for both PUCCH and PUSCH. For Option. 2, it is required to specify how to indicate one of two beams to apply the TPC value and how to indicate whether the TPC value is applied to one beam or two beams. |
| Oppo | Proposal 13: Do not support the use of different PUCCH resources for multi-TRP PUCCH enhancements.  Proposal 14: Support PUCCH format 0/2 with multi-TRP PUCCH transmission.  Proposal 15: Support repetition number(2,4,8) specified in Rel-15 as a total repetition number with different beams for multi-TRP inter-slot repetition.  Proposal 16: Support another default set of P0 and, Pathloss referenceSignal and closed loop index for PUCCH power control for different TRP for FR1.  Proposal 17: For power control of PUCCH, support option 1 or 4.   * 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 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. |
| Sony | Proposal 1: Support combination of multi-TRP intra-slot beam hopping (Scheme 2) and multi-TRP intra-slot repetition (Scheme 3)  Proposal 2: The inter-slot repetition (Scheme 1) should reuse the same intra-slot beam hopping pattern and/or the same intra-slot repletion pattern. |
| Apple | Proposal 3-1: Support inter-slot multi-beam repetition for PUCCH format 0/2.  Proposal 3-2: To avoid overlap with other AI, the decision on whether to support intra-slot PUCCH beam hopping/repetition should be deferred.  Proposal 3-3: Dynamic indication of number of PUCCH repetitions should not be discussed in MIMO AI.  Proposal 3-4: Support to introduce a MAC CE to update the power control parameters for a PUCCH resource or a list of PUCCH resources for FR1, which includes up to 2 P0, up to 2 pathloss RS, and up to 2 closed-loop indexes.  Proposal 3-5: For TPC command for PUCCH with two closed-loop power control processes, support 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)   * Support to introduce higher layer signaling to configure the indication of the TPC command   Proposal 3-6: It should be supported that the first PUCCH-spatialRelationInfo activated for PUCCH resource with lowest ID should be selected to determine the beam of PUSCH when it is scheduled by DCI format 0\_0. |
| LG | Proposal 19: For MTRP PUCCH transmission, TA should be configured separately for different transmission occasion.  Proposal 20: For MTRP PUCCH transmission, consider configuration of multiple PUCCH resources, additionally.  Proposal 21: If details on STRP based intra-slot PUCCH repetition is agreed in Rel-17 IIoT/URLLC WI, discuss extension to MTRP (scheme 3) as we do for inter-slot PUCCH repetition.  Proposal 22: Support intra-slot beam hopping (scheme 2) for both low latency and high reliability.  Proposal 23: For TRP specific power control for a PUCCH resource in FR1, associate the PUCCH resource with the 1st and 2nd lowest ID PC parameters in PUCCH-PowerControl in PUCCH-Config.  Proposal 24: For per-TRP closed-loop power control for PUCCH/PUSCH, introduce two TPC field or extend TPC field to indicate two TPC values.  Proposal 25: Beam mapping should be clarified in the specification when some of PUCCH TOs are dropped due to flexible DL symbols. |
| Nokia/NSB | Proposal 10: For the multi-TRP PUCCH repetition, wait for RAN4’s reply to the LS regarding the range of beam switching gaps before discussing further the aspect on beam mapping applicability.  Proposal 11: Support the multi-TRP PUCCH intra-slot repetition scheme.  Proposal 12: Do not consider further the multi-TRP PUCCH intra-slot beam hopping scheme.  Proposal 13: For multi-TRP PUCCH scheme 1, support of PUCCH formats 0 and 2.  Proposal 14: For multi-TRP PUCCH scheme 3 (intra-slot repetition), support PUCCH formats 0 and 2.  Proposal 15: Support dynamic indication of PUCCH repetition number for multi-TRP PUCCH repetition operation.  Proposal 16: For the indication of two TPC commands via UE-specific PDCCH for multi-TRP PUCCH repetition operation, support option 3, i.e., a second TPC field is added in DCI formats 1\_1 / 1\_2.  Observation 1: The existing procedures do not allow the network to separately adapt the PUCCH power control parameters for the different beams/TRPs for multi-TRP PUCCH schemes in FR1.  Proposal 17: To enable the support of separate power control for different TRPs for multi-TRP PUCCH schemes in FR1, a PUCCH resource is linked to two subsets of PUCCH power control parameters.   * FFS the related indication and configuration.   Proposal 18: For multi-TRP PUCCH schemes, if the UE is not provided pathlossReferenceRSs, define how to enable the UE to determine two RS resources needed to calculate two pathloss values for PUCCH power control.  Proposal 19: For multi-TRP PUCCH schemes, if the UE is not provided pathlossReferenceRSs, consider the following aspects/parameters for the determination of two RS resources needed for the calculation of two pathloss values: the TRP scheme in downlink, the TCI state or QCL assumption of at least one CORESET and/or the TCI states of PDSCH.  Proposal 20: Support dynamic switching between multi-TRP PUCCH schemes and single-TRP PUCCH scheme in both FR1 and FR2.   * FFS the details of such switching. |
| Lenovo/Motorola Mobility | Proposal 19: Support at least sub-slot based intra-slot PUCCH repetition.  Proposal 20: Further clarify whether a PUCCH resource can be configured as intra-slot PUCCH repetition where the PUCCH resource is configured with slot based PUCCH transmission.  Proposal 21: Study the method of handling the beam switching time of two adjacent PUCCH repetitions with different beam and select between the two ways of dropping symbols of repetition(s) and delaying later repetition in R17.  Proposal 22: Consider the multiplexing of UCI to support UCI repetition in different PUCCH resources within a slot or different slots.  Proposal 23: For UCI repetition with multiple PUCCH resources, configure multiple PUCCH resources by RRC for periodic UCI, semi-persistent CSI, SR or HARQ-ACK corresponding to SPS PDSCH, and further study how to indicate multiple PUCCH resource by the scheduling DCI for HARQ-ACK with DCI scheduling.  Proposal 24: Support Option 1, 3 and 4 while Option 1 is preferred.  Proposal 25: Configured two predefined power control parameter sets for a PUCCH with repetition in FR1, and configure a mapping pattern like beam mapping pattern for indicating the power control parameter set where each repetition is associated.  Proposal 26: Support short PUCCH formats for PUCCH repetition and support dynamic indication of the number of PUCCH repetitions for PUCCHs carrying HARQ-ACK corresponding to PDSCH with DCI scheduling.  Proposal 27: Perform frequency hopping across PUCCH repetition per beam. |
| Intel | Proposal-18: Support dynamic switching between s-TRP/m-TRP PUCCH repetitions by associating a PUCCH resource with one or two (ordered) spatial-relation-info and PRI bit-field indicating a PUCCH resource. Introduce additional PUCCH groups that includes all and only PUCCH resources that are associated with 2 ordered spatial-relation info.  Proposal-19: Support option 1 and option 3. For option 3, whether to use 2 (TRP-1) + 2 (TRP-2) = 4 bits or 1 (TRP-1) + 1 (TRP-2) = 2 bits field-size can be aligned with the same issue in PUSCH.  Proposal-20: Support inter-slot repetition (Scheme 1) and intra-slot repetition (Scheme 2) for PUCCH to allow both soft-combining reception and much simpler selection diversity reception at the gNB  Proposal-21: Confirm the working assumption to support both cyclical and sequential mapping of UL beams for PUCCH repetitions.  Proposal-22: Support multi-TRP repetition for short PUCCH formats 0, 2 (scheme 1 and scheme 2) in order to achieve reliability with low latency (1-2 symbol length per repetition) |
| Xiaomi | Proposal 26: Support Scheme 2 and Scheme 3 for PUCCH transmission for intra-slot transmission.  Proposal 27: The repetition number for Scheme 1 can be extended to 16.  Proposal 28: Scheme 2 can be beneficial, but more than 2 hops are not expected considering the complexity and the spec impacts.  Proposal 29: Support PUCCH format 0/2 for inter-slot repetition.  Proposal 30: Support all PUCCH formats for intra-slot repetition scheme(s).  Proposal 31: Dynamic indication can be achieved on a resource level configuration, or by activating the suitable repetition number for the certain PUCCH resource with the MAC-CE signaling from a set of RRC-configured candidate values.  Proposal 32: We prefer option 3 for the TPC enhancement for multi-TRP based PUCCH transmission.  Proposal 33: Agree with the WA. Support cyclical mapping for multi-TRP PUCCH/PUSCH transmission if the beam switching gap is comparable to the antenna switching gap (1or 2 symbols).  Proposal 34: Assuming the switching gap between panels are comparable to the switching gap for antenna switching, MPUE assumption 2 and/or 3 are feasible for multi-TRP PUSCH/PUCCH transmission. |
| Spreadtrum | Proposal 13: Support to study multi-TRP intra-slot repetition (scheme 3) with first priority.  Proposal 14: All PUCCH formats should be supported for scheme 3.  Proposal 15: PUCCH format 0/2 should be supported for scheme 1.  Proposal 16: Supporting dynamic indication of the number of PUCCH repetitions by reusing existing DCI filed, such as PRI, PDSCH-TO-ACK field.  Proposal 17: For multi-TRP PUCCH transmission, support Option4 for power control function.  Proposal 18: For FR1, the enhanced TPC field in DCI can be used to implicitly indicate single-TRP transmission or multi-TRP transmission |
| Covinda | Proposal 7: The basic Scheme 1 is finalized before the following additions are discussed: format 0/2 for Scheme 1, dynamic indication of repetitions, and repetitions across multiple PUCCH resources.  Proposal 8: Support Option 3: A second TPC field is added in DCI formats 1\_1 / 1\_2. |
| NTT Docomo | Proposal 4-1:   * Support one of intra-slot beam hopping and intra-slot repetition.   Proposal 4-2:   * Support inter-slot M-TRP PUCCH repetition for PUCCH format 0/2. * Support intra-slot M-TRP PUCCH repetition for at least short PUCCH formats, if intra-slot repetition is supported. * Support intra-slot M-TRP PUCCH beam hopping for all PUCCH formats, if intra-slot beam hopping is supported.   Proposal 4-3:   * Support one PUCCH resource activated with one or two spatial relation infos via MAC CE.   Proposal 4-4:   * For M-TRP PUCCH repetition, a second TPC field is added in DCI formats 1\_1/1\_2.   Proposal 4-5:   * For M-TRP PUCCH repetition, when PUCCH spatial relation is not provided, study new rules to determine two P0-PUCCH/PL-RS/closeloopIndex. * Same mapping pattern as defined for beam mapping can be applied to the mapping between different power control parameters and repetitions   Proposal 4-6:   * For FR1, further study whether to support dynamic switching between S-TRP and M-TRP PUCCH repetition. |
| Ericsson | [Proposal 22 Intra-slot beam hopping (Scheme 2) is not supported in NR Rel-17.](#_Toc61892571)  [Proposal 23 Support Multi-TRP intra-slot repetition (Scheme 3) in NR Rel-17](#_Toc61892572)  [Proposal 24 Both short and long PUCCH formats are supported for Intra-slot repetition](#_Toc61892573)  [Proposal 25 For per TRP closed-loop power control for PUCCH, support either Option 3 (two TPC fields in DCI 1\_1/1\_2) or Option 4 (one codepoint in TPC field indicating two TPC values) in NR Rel-17.](#_Toc61892574) |
| Qualcomm | Proposal 14: 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. * The configured value of secondHopPRB can be the same as or different than startingPRB.   Proposal 15: If the support of sub-slot based PUCCH repetition with single-beam is agreed in other agenda items, extend it to multi-TRP (i.e., Scheme 3) by reusing the mechanisms of Scheme 1.  Proposal 16: For multi-TRP TDM-ed PUCCH transmission schemes, support PUCCH formats 0 and 2 addition to PUCCH formats 1, 3, and 4.  Proposal 17: For scheme 1, support configuring both nrofSlots and interslotFrequencyHopping per PUCCH resource to enable more dynamic and flexible signalling.  Proposal 18: When inter-slot frequency hopping is enabled for Scheme 1, frequency hopping is performed among the repetitions with the same beam.  Proposal 19: For PUCCH multi-TRP enhancements in FR1, reuse PUCCH spatial relation including reusing exiting RRC and MAC-CE.   * “referenceSignal” in IE PUCCH-SpatialRelationInfo can be configured with a “null” value in FR1.   Proposal 20: For TPC command in DCI formats 1\_1 / 1\_2, if the “closedLoopIndex” values associated with the two PUCCH spatial relation info’s are different for multi-TRP PUCCH transmission schemes, support:   * Option 4: A single TPC field is used in DCI formats 1\_1 / 1\_2 (2 bits), and indicates two TPC values applied to two PUCCH beams, respectively (first preference).   + Support a mapping between TPC field codepoints and a pair of TPC commands. * Option 1: A single TPC field is used in DCI formats 1\_1 / 1\_2, and the TPC value applied for both PUCCH beams (second preference). |

## 5.2 Proposals on PUSCH

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| Company | Proposals |
| FutureWei | Proposal 8: For M-TRP codebook based PUSCH transmission, support two separate SRI fields and two separate TPMI fields, each of the field corresponds to the one TRP and existing field design should be reused.  Proposal 9: For M-TRP non-codebook based PUSCH transmission, support two separate SRI fields.  Proposal 10: For M-TRP PUSCH power control, configure multiple separate sets of PUSCH power control parameters, each set associated with one TRP in RRC configuration and including TRP-specific open-loop parameters, closed-loop parameters, and spatial relation info and/or pathloss RS, and   * Support 2 TPC fields in DCI formats 0\_1, 0\_2, and 2\_2, each TPC field is configured for one TRP; * Reword to when the “closedLoopIndex” values are for different closed-loops.   Proposal 11: For M-TRP PUSCH enhancement, also support M-DCI based PUSCH transmission/repetition scheme(s) based on Rel-16 PUSCH repetition Type A and Type B.  Proposal 12: For M-TRP PUSCH enhancement, support two separate sets of TRP-specific TA offsets, each associated with a set of PUSCH configurations and all other UL transmissions QCLed/associated with it, and the TA offset is relative to the associated TRP-specific DL reference timing (e.g., the associated DL symbol starting time).  Proposal 13: Confirm the Working Assumption to support Alt3 (Two SS sets associated with corresponding CORESETs), and increase the number of CORESETs to up to 5.  Proposal 14: For Case 1: Two (or more) PDCCH candidates are explicitly linked together (UE knows the linking before decoding), support a limited set of RRC configured linkages between the PDCCH candidates.  Proposal 15: For the BD count for Option 2 + Case 1 with up to two PDCCH candidates, specify the lower bound as 1 BD per DCI and the upper bound as   * 2 BDs per DCI if dynamic network selection is not enabled; and * 3 BDs per DCI otherwise.   Proposal 16: For multi-TRP UL enhancement, support to acquire and maintain multiple TA values for multiple TRPs on the same carrier via PRACH enhancement and TA configuration enhancement. |
| InterDigital | Proposal 4: To support PUSCH beam switching, multiple PUSCH mapping patterns are RRC configured, and one is dynamically indicated by a DCI.  Proposal 5: Support Alt. 1 with some enhancements to dynamically select CG spatial filters. |
| NEC | Proposal 5: For codebook based single-DCI PUSCH transmission, support Alt 1. And the two SRIs should be designed to support dynamic switching between single-TRP and multi-TRP transmission.   * Alt1: Bit field of SRI shall be enhanced.   Proposal 6: For codebook based single-DCI PUSCH transmission, support two TPMI fields to indicate the RI and two TPMIs, and overhead for the second TPMI field can be reduced based on the same number of layers for the two TPMIs.  Proposal 7: For non-codebook based single-DCI PUSCH transmission, support two SRIs indication. And the SRI indication should be designed to support dynamic switching between single-TRP and multi-TRP transmission.  Proposal 8: For closed-loop power control for PUSCH and PUCCH, a second TPC field should be added in DCI (i.e. Option 3). |
| Vivo | Proposal 18: Support M-DCI based PUSCH repetition scheme with minimum spec impact.  Proposal 19: Support Option2& Option3 to enable M-DCI based PUSCH repetition schemes as a starting point.  Proposal 20: For S-DCI PUSCH enhancement, support to dynamically switch between single TRP and multiple TRP with SRI, and the order of targeting TRPs can also be dynamically indicated. The following ways can be further discussed  • Explicitly indicated by SRI field.  • Implicitly indicated.  Proposal 21: Enhancement of SRI fields should also consider support of full power transmission mode.  Proposal 22: Mapping of codepoint to two SRIs can be activated by MAC CE, similar as that of two TCI states indication in Rel-16 MTRP PDSCH enhancement.  Proposal 23: MAC CE can be introduced to select a subset of TPMI combination to reduce DCI overhead.  Proposal 24: In FR1, PUSCH repetitions transmitting towards MTRP can share the same TPMI.  Proposal 25: For PUSCH repetitions transmitting towards two TRPs, up to two power control parameter sets are required.  Proposal 26: The following method is preferred to acquire more than one sets of power control parameters:   One SRI field selects two SRI-PUSCH-PowerControl from two sri-PUSCH-MappingToAddModList.  Proposal 27: A single TPC field in DCI formats 0\_1 / 0\_2 (Option 4) can be used to indicate two TPC values applied to two PUSCH beams, respectively.  Proposal 28: Further study enhancement of open-loop power control parameter set indication field.  Proposal 29: To support single DCI based PUSCH towards M-TRP, PTRS-DMRS association field needs to be enhanced.  Proposal 30: For the case if maximum transmission layers are limited to 2:   There is no need to increase bit width of PTRS-DMRS association field   The two bits can be reinterpreted.  Proposal 31: For RV mapping for PUSCH repetition Type B, same method in repetition Type A can be reused for PUSCH repetition Type B.  Proposal 32: Alt.2 is preferred for CG enhancement in MTRP scenario.  Proposal 33: Further discuss Power control of CG retransmission.  Proposal 34: There is no need to introduce half-half mapping pattern.  Proposal 35: The association between frequency hopping pattern and beam pattern should be properly selected.  Proposal 36: Support slot index dependent beam mapping for PUSCH repetition Type B.  Proposal 37: For PUSCH repetition Type A scheduled with 1 repetition, beam switching of PUSCH is applied for the two hops |
| ZTE | Proposal 2-1: Support that two TPMI fields in DCI for multi-TRP PUSCH transmission with codebook based scheme, where TPMI field 1 is the same as Rel-16, TPMI field 2 is the part of TPMI field 1 with the same transmission rank.  Proposal 2-2: Support dynamic switching between single-TRP and multi-TRP operations for PUSCH enhancements.  Proposal 2-3: Support to exploit some reserved entries in TPMI filed 2 to indicate dynamic switching between single-TRP and multi-TRP operations for codebook based PUSCH transmission.  Proposal 2-4: Support two SRI fields in DCI for multi-TRP PUSCH transmission with codebook based scheme, where the DCI overhead of each SRI field is 0 or 1 bit.  Proposal 2-5: Support that the transmission ranks between two TRPs should be same for non-codebook based multi-TRP PUSCH repetition.  Proposal 2-6: Support two SRI fields in DCI for multi-TRP PUSCH transmission with non-codebook based scheme.  Proposal 2-7: Support to exploit some entries in SRI filed 2 to indicate dynamic switching between single-TRP and multi-TRP operations for non-codebook based PUSCH transmission.  Proposal 2-8: Support that two sets of default values of power control parameters are used for two TRPs when SRI field 1 and/or SRI field 2 absent in DCI.  Proposal 2-9: For PUSCH PL-RS updated by MAC CE for multi-TRP PUSCH transmission scheme, support to use one reserved bit in the current PUSCH Pathloss Reference RS Update MAC CE to enable TRP-specific PUSCH PL-RS update.  Proposal 2-10: For the indication of PTRS-DMRS association in multi-TRP PUSCH transmission,   * in the case of rank 2, reusing the existing indication of PTRS-DMRS association in DCI, where MSB and LSB can be used for two TRPs respectively. * in the case of rank 3 or 4, the existing indication of PTRS-DMRS association in DCI can be used for TRP1, and some remaining entries/bits of DM-RS port indication can be used for TRP2. |
| Fujitsu | Proposal 6: For single DCI based PUSCH multi-TRP enhancements, reuse the same RV mapping method 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.   Proposal 7: For power control enhancement on multi-TRP PUSCH, support 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.   Proposal 8: For multi-TRP CG PUSCH transmission, support the framework of single CG configuration (Alt. 1). |
| MediaTek | Proposal 14: Option 3, i.e., a second TPC field is added in DCI formats 0\_1 / 0\_2, is supported for per TRP closed-loop power control for PUSCH.  Proposal 15: Single CG configuration is adopted to support CG PUSCH transmission towards multi-TRP. |
| CATT | Proposal 11: To achieve similar flexibility per TRP as in single-TRP case, the configuration of the SRS resource(s) in each SRS resource set with usage set to ‘codebook’ or ‘non-codebook’ can follow the rules of current specs.  Proposal 12: For MTRP codebook based PUSCH via S-DCI, two separate SRI fields or one joint SRI field in DCI can be supported.  Proposal 13: For MTRP codebook based PUSCH via S-DCI, one joint TPMI field indicating two TPMIs is slightly preferred considering possible overhead reduction compared with two separate TRMI fields.  Proposal 14: For MTRP PUSCH repetitions via S-DCI, dynamic switch between single beam and two TDMed beams is supported. In case of two beams switched to only one beam, the PUSCH repetition number of the indicated beam should follow the rules for single TRP in Rel-16.  Proposal 15: For separate MTRP PUSCH close-loop power control via S-DCI, option 3 or 4 can be chosen.   * 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.   Proposal 16: For M-TRP CG PUSCH, single CG configuration is supported. |
| Apple | Proposal 4-1: For PUSCH with multi-beam repetitions, 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   Proposal 4-2: Support to report two actual PHRs corresponding to the two beams for the PUSCH repetitions when the PHR is triggered.  Proposal 4-3: Support Alt1 (single CG configuration) for CG-PUSCH with mTRP operation.  Proposal 4-4: Do not support multi-DCI based PUSCH  Proposal 4-5: For TPC command indication for PUSCH repetitions with 2 closed-loop power control processes, support 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)   * Support to introduce higher layer signaling to configure the indication of the TPC command |
| Fraunhofer IIS/HHI | Proposal 11: A MAC-CE command shall be created for the activation/deactivation of multiple SP-SRS resource sets.  Proposal 12: The association of the SRI fields with the SRS resource sets transmitted before the PUSCH scheduling shall be made similar to the association in Rel-15/16.  Proposal 13: Use single configuration of higher layer configured grant to schedule M-TRP PUSCH repetition with 2 SRIs and 2 TPMIs (in the case of codebook PUSCH).  Proposal 14: For the indication of the two SRIs, Alt-1 is chosen: Bit field of SRI shall be enhanced.  Proposal 15: Use the same number of layers for the two indicated TPMIs.  Proposal 16: No restrictions regarding the number of SRS ports are used between the TRPs for codebook-based multi-TRP PUSCH repetition.  Proposal 17: For the indication of 2 TPMI values, one TPMI field shall be used and the field shall be enhanced to indicate two values. |
| Lenovo/Motorola Mobility | Proposal 28: Spatial relation and PL-RS for PUSCH scheduled by DCI format 0\_0 should be determined when a PUCCH resource with lowest ID is activated with two spatial relations.  Proposal 29: PUSCH transmission scheme without repetition is lower priority compared with the schemes of PUSCH repetition Type A and Type B.  Proposal 30: To support the indication of two SRIs, Alt 1 is preferred.  Proposal 31: To support the indication of two TPMIs, use TPMI index restriction like codebook subset restriction in DL if there is no change on TPMI field.  Proposal 32: Support the way of dropping symbols of two adjacent PUSCH repetitions with different beams in order to make sure the time for beam switching.  Proposal 33: Study how to determine the dropped symbols and determine whether the dropped symbols of PUSCH repetition Type B are invalid symbols or not.  Proposal 34: Support Option 1, 3 and 4 while Option 1 is preferred.  Proposal 35: Enhance SRI-PUSCH-PowerControl to be able to indicate two power control parameter sets for PUSCH with repetition in R17. |
| Intel | Proposal-11: In order to support dynamic switching of mTRP/sTRP repetitions, enable dynamic switching of SRS resource sets for CB/NCB based PUSCH repetitions. The DCI indicated SRI(s) can be conditioned on the indicated SRS resource set(s).  Proposal-12: Re-interpret SRI field as a value pair (TRP-1, TRP-2) based on RRC/DCI to support dynamic switching of sTRP/mTRP operation.  Proposal-13: Use a common framework to convey TRP specific information like TPC, PTRS-DMRS, beta offset indicator, OLPC parameter selection and DMRS sequence init. Enable a basic mechanism where a single value is applied for both TRPs. Enable an advanced mechanism where the DCI field is re-interpreted as a value-pair (TRP-1, TRP-2) based on RRC/DCI.  Proposal-14: Consider extending precoder information and layer information (PINL) tables including entries indicating a layer and TPMI-pair information.  Proposal-15: Support inter-slot repetition for PUSCH Type A  Proposal-16: Confirm the working assumption to support both cyclical and sequential mapping of UL beams for PUSCH repetition Type A and Type B.  Proposal-17: Specifications for multi-DCI multi-TRP PUSCH transmission is not well motivated considering UE processing flow impact, specification impact to resolve TBS determination issue, and PDCCH overhead/reliability issues |
| Oppo | Proposal 18: The number of layers for PUSCH reliability enhancements is limited to <= 2.  Proposal 19: No changes are needed for the size of PTRS-DMRS indication field when the number of layers for PUSCH reliability enhancements is limited to <= 2.  Proposal 20: Support two SRI fields for codebook based PUSCH transmission.  Proposal 21: For codebook based PUSCH transmission, support 2 TPMI fields and 1st TPMI indicates PMI for TRP 1 and RI while 2nd TPMI indicated PMI for TRP2  Proposal 22: For non-codebook based PUSCH transmission, support 2 SRI fields and 1st SRI indicates SRS resource(s) for TRP 1 and RI while 2nd SRI indicates SRS resource(s) for TRP 2.  Proposal 23: Support single CG configuration for type1 and type 2CG PUSCH transmission towards MTRP.  Proposal 24: Support single TPC field in UL DCI and the TPC value applied to both PUSCH beams or a single TPC field indicated two TPC values applied to two PUSCH beams (Option 1 or 4).  Proposal 25: Do not support slot based beam mapping for Type B in the case of nominal repetition crosses slot boundaries.  Proposal 26: Support sequential mapping for PUSCH repetition targeting multi-TRP when repetition number is equal to or larger than 4.  Proposal 27: Support the same RV mapping method for PUSCH repetition type B as PUSCH repetition type A. RV cycling is done across the actual repetition as specified in Rel-16 for PUSCH URLLC.  Proposal 28: UE transmit PUSCH scheduled by DCI 0\_0 according to the 1st PUCCH-spatialrelationinfo if two spatial relation infos are activated by MAC-CE for dedicated PUCCH with the lowest ID. |
| Samsung | Proposal 14. Support multi-DCI based multi-TRP PUSCH repetition scheme for flexible resource allocation across repetitions.  Proposal 15. Support the details when two SRS resource sets are configured for usage of both codebook and non-codebook based PUSCH   * 1st and 2nd SRI of indicated SRIs are applied to the 1st and 2nd SRS resource sets, respectively. * 1st and 2nd SRI of indicated SRIs in slot n can be associated with the most recent transmission of SRS resources in the 1st and 2nd SRS resource sets, respectively, identified by the SRI, where the SRS resources are prior to the PDCCH carrying the SRI. * Two srs-PowerControlAdjustmentStates included in both SRS-ResourceSets have same value as sameAsFci2.   Proposal 16. Introduce enhanced timing relationship between SRS and CG PUSCH to allow automatic beam update for the CG PUSCH in order to follow the configured/activated spatial relation for SRS.  Proposal 17. The enhancement on PTRS-DMRS association for single-DCI based multi-TRP PUSCH repetition is not necessary. |
| CMCC | Proposal 9: Multi-DCI based PUSCH scheduling should be considered for multi-TRP URLLC PUSCH transmission.  Proposal 10: Configuring one or up to two SRS resources in a resource set could be considered for codebook based PUSCH repetition.  Proposal 11: Support the enhancement on bit field of SRI for codebook based PUSCH repetition (Alt 1).  Proposal 12: Support adding a second TPC field in DCI formats 0\_1 / 0\_2 (Option 3) for Multi-TRP PUSCH power control enhancement.  Proposal 13: On the mapping between PUSCH repetitions and beams, for both PUSCH repetition Type A and B, support cyclical mapping and sequential mapping pattern. |
| Spreadtrum | Proposal 8: For indication of two SRI/TPMI values, support to reuse SRI/TPMI field with different interpretations to indicate two SRI/TPMI values respectively.  proposal 9：For single-DCI based PUSCH, a new MAC CE can be considered for the enhancement on PTRS-DMRS association.  Proposal 10: For multi-TRP operation, support Option4 for PUSCH power control.  Proposal 11: Not support slot based beam mapping for PUSCH repetition type B.  Proposal 12: Not support half-half beam mapping for PUSCH enhancement. |
| Ericsson | [Proposal 12 For codebook/non-codebook based multi-TRP PUSCH, support two separate SRI fields in DCI, where the first SRI field indicates the SRI(s) corresponding to the first TRP and the second SRI field indicates the SRI(s) corresponding to the second TRP.](#_Toc61892561)  [Proposal 13 For codebook based multi-TRP PUSCH, support two separate TPMI fields in DCI, where the first TPMI field indicates the TPMI corresponding to the first TRP and the second TPMI field indicates the TPMI corresponding to the second TRP. The number of layers indicated in the first TPMI field and the second TPMI field are the same.](#_Toc61892562)  [Proposal 14 For per TRP closed-loop power control for PUSCH, Option 3 is supported where a second TPC field is added in DCI formats 0\_1 / 0\_2.](#_Toc61892563)  [Proposal 15 Dynamic switching between PUSCH transmission to a single-TRP and multi-TRP should be supported, i.e. each PUSCH transmission is either targeting reception at one or at two TRPs.](#_Toc61892564)  [Proposal 16 Two SRI/TPMI fields are supported for PUSCH repetition towards m-TRP.](#_Toc61892565)  [Proposal 17 To dynamically indicate PUSCH transmission towards a single-TRP or multiple-TRPs, each SRI/TPMI field contains a codepoint that indicates whether the SRI/TPMI field is disabled or not.](#_Toc61892566)  [Proposal 18 For CG PUSCH transmission towards multiple TRPs, support Alt.1.](#_Toc61892567)  [Proposal 19 Reuse the same RV mapping method as in PUSCH repetition Type A for PUSCH repetition Type B](#_Toc61892568)  [Proposal 20 Consider allowing back-to-back scheduling of PUSCH repetitions via multiple DCIs over multiple TRPs in NR Rel-17.](#_Toc61892569)  [Proposal 21 To improve A-CSI reliability, support A-CSI multiplexing on at least two PUSCH occasions towards different TRPs in NR Rel-17.](#_Toc61892570) |
| Huawei | Proposal 11: For the case with full power transmission mode-2, two SRS resources can be configured for each SRS resource set corresponding to each TRP; otherwise, one SRS resource is configured for each SRS resource set.  Proposal 12: Support Alt 1, i.e., the bit field of SRI is enhanced, to enable dynamic switching between single-TRP and multi-TRP based PUSCH transmission.  Proposal 13: For the enhancement on TPMI field, use one TPMI table to jointly indicate two TPMIs.  Proposal 14: The same coherent type is assumed for both TPMIs in multi-TRP PUSCH transmission.  Proposal 15: For non-codebook based PUSCH transmission, the same rank is assumed for the two TRPs.  Proposal 16: For non-codebook based PUSCH transmission, for the enhancement on SRI field, use one SRI table to indicate SRS resources from the two SRS resource sets.  Proposal 17: Both sequential and cyclic beam mapping pattern for PUSCH transmission with more than two repetitions should be supported.  Proposal 18: For per TRP closed-loop power control for PUSCH transmission, support Option 2.  Proposal 19: For CG PUSCH transmission, Alt.1 (single CG configuration) should be supported.  Proposal 20: Support CSI piggyback on two PUSCH repetitions with different beams. |
| Xiaomi | Proposal 10: For multi-TRP based PUSCH, the maximum number of transmission layers is up to 2 per transmission occasion or per panel.  Proposal 11: For multi-TRP based PUSCH, consider to re-specify up to 2-layer transmission for PUSCH repetition Type A.  Proposal 12: For multi-TRP based PUSCH, consider to increase the maximum number of repetitions to 32 especially in FR2.  Proposal 13: The TBS determination rule for PUSCH repetition Type A and Type B defined in Rel-16 can be reused.  Proposal 14: For CB based PUSCH, enhancements are suggested as below:   1. Extend the SRI field to indicate the SRIs targeting each TRP; 2. Two TPMI/RI fields to indicate two precoders associated with spatial relation filters separately; 3. no extension is needed for the number of SRS resources configured within a SRS resource set;   Proposal 15: For NCB based PUSCH with multi-TRP, enhancements are suggested as below:   1. Extend the SRI field to indicate the spatial relations of SRS subsets; 2. Maximum number of SRS resources within a resource set maintains 4;   Proposal 16: For the TPC indication, option 3 is more preferred.  Proposal 17: For multi-TRP PUSCH repetition type A, the scheme of beams mapping onto repetitions should consider the dropping of invalid transmission occasions.  Proposal 18: For repetition type A, beams targeting different TRPs are applied to the actual transmission occasions of the TB (with the counting not including the omitted ones) as well as nominal repetitions, which can be configurable.  Proposal 19: The beams mapping to repetitions need to consider how to deal with the orphan symbol(s) for repetition Type B.  Proposal 20: Transmitting the DMRS symbol instead of dropping of the orphan symbol(s) for multi-TRP based PUSCH, with applying the beam mapped onto that repetition occasion.  Proposal 21：Method 1: 1-bit Group DCI indicating the PUSCH cooperated-TRP mode can be used for further decoding of the UE-specific DCI, which support the dynamic switching between single TRP and multi-TRP based transmission.  Proposal 22 Method 2: Group DCI bits indicates the beam mapping scheme of PUSCH explicitly and also the PUSCH transmission mode implicitly which can be used for further decoding of the UE-specific DCI. This two-step DCI method can support the dynamic switching between single TRP and multi-TRP based transmission.  Proposal 23: dynamic indication of the beam mapping scheme can be considered for multi-TRP PUSCH repetitions, two options are suggested:   * Alt.1: The beam mapping scheme is determined by both the beam mapping pattern and the repetition type. The beam mapping pattern (cyclical, sequential, half-half, etc.) can be configured by RRC which is more related to UE capability, and the repetition type(nominal repetitions, actual repetitions, slots, etc.) that the beams mapping onto can be further indicated by DCI, or vice versa. * Alt.2: The beam mapping scheme applied to the scheduled PUSCH is indicated by group DCI with beam mapping scheme codepoint. The codepoint mapping table of beam mapping scheme is pre-defined or configured by RRC signaling, one or multiple codepoint(s) can be designed to indicate the mapping pattern when the scheduled PUSCH is in a single TRP transmission mode.   Proposal 24: support Rel-15/16 URLLC sequence {0,2,3,1} at least, and other RV sequences, such as {0,0,0,0} , {0,3,0,3} can also be considered.  Proposal 25: for the RV indication, the following methods are suggested, our preference is option 2.   * Option 1: One RV sequence is configured for all repetitions regarding two beams. The current RV field indicates the initial RV value targeting TRP 1, and the RV with an offset can be applied for TCI 2 with an offset value. The parameter offset needs to be pre-defined in spec or RRC configured. * Option 2: RV initial values or RV offset values for repetitions targeting both TRPs can be indicated jointly by RV codepoint. The RV codepoint can be pre-determined by network or pre-defined in spec, which may contain most possible combinations the network expects to apply for a dynamic RV configuration. |
| Sharp | Proposal 1: For the indication of the two SRIs, Alt1 (Bit field of SRI shall be enhanced) is preferred.  Proposal 2: For per TRP closed loop power control, Option 3 (A second TPC field is added in DCI formats 0\_1 / 0\_2) is preferred. |
| LG | Proposal 8: For MTRP PUSCH transmission, separate TA configuration for each TRP should be supported considering the difference of propagation delay, inter-panel delay, and compatibility to above 52.6GHz.  Proposal 9: Limit the max rank for MTRP PUSCH transmission to 2.  Proposal 10: Extend bit size of a SRI field, and each codepoint indicates one or two SRS resources and one or two PC parameters for STRP PUSCH transmission or MTRP PUSCH transmission.  Proposal 11: Consider introducing one more TPMI field for 2nd TRP without RI information and codebook subsampling.  Proposal 12: Extend bit size of a SRI field, and each codepoint indicates SRS resource(s) for one or two SRS resource sets.  Proposal 13: Apply the same rank restriction for MTRP non-codebook based PUSCH.  Proposal 14: Apply the same RV pattern for MTRP Type B PUSCH repetition as Type A.  Proposal 15: Beam mapping should be clarified in the specification when some of PUSCH TOs are dropped for type A/B repetition and when a PUSCH TO is split across slot boundary for type B repetition.  Proposal 16: single PUSCH transmission with beam hopping can be considered, additionally.  Proposal 17: Support M-DCI based MTRP PUSCH transmission for CG PUSCH and DG PUSCH.  Proposal 18: For TRP specific PTRS-DMRS association, MSB indicates PTRS-DMRS association for TRP 1 and LSB indicates PTRS-DMRS association for TRP 2. |
| Covinda Wireless | Proposal 9: Support up to two SRS resources in each of the two SRS resource sets with usage codebook.  Proposal 10: Support Alt1: Bit field of SRI shall be enhanced. One or two SRS resources from the two SRS resource sets can be indicated.  Proposal 11: Support a second TPMI field with fewer bits since the number of layers is given by the first TPMI.  Proposal 12: Support up to two SRS resources in each of the two SRS resource sets with usage non-codebook.  Proposal 13: Support Option 3: A second TPC field is added in DCI formats 0\_1 / 0\_2. |
| Asia Pacific Telecom | Proposal 1: Half-half mapping pattern should not be support.  Proposal 2: A more dynamic scheduling for beam switching gaps should be considered.  Proposal 3: It would be beneficial to configure some configurations (e.g., invalid symbol pattern) or parameters per TRP rather than per BWP for multi-TRP operation.  Proposal 4: Bit field enhancement for the indication of 2 TPMIs and 2SRIs is necessary. Foe simplicity, 2 TPMI and 2 SRI field are included in one DCI is preferred.  Proposal 5: For signaling overhead reduction, we support option 2 for PUSCH/PUCCH close-loop power control.  Proposal 6: For TRP-based PUSCH transmission, it could be limited to low rank transmission for signaling overhead reduction.  Proposal 7: Support multiple CG configurations for multi-TRP PUSCH transmission. |
| NTT DOCOMO | Proposal 3-1:   * For single DCI based M-TRP PUSCH repetition, for both CB and NCB based PUSCH Tx, indicate two SRI fields in DCI. * For both CB and NCB based PUSCH Tx, two SRI fields are mapped to two SRS resource sets, respectively   Proposal 3-2:   * For single DCI based M-TRP PUSCH repetition, for CB based PUSCH Tx, indicate two TPMI fields in DCI.   Proposal 3-3:   * For single DCI based M-TRP PUSCH repetition, a second TPC field is added in DCI format 0\_1/0\_2.   Proposal 3-4:   * For M-TRP PUSCH repetitions, when SRI is not provided, study new rules to determine two P0-PUSCH/alpha/PL-RS/closeloopIndex. * Same mapping pattern as defined for beam mapping can be applied to the mapping between different power control parameters and repetitions   Proposal 3-5:   * Further study whether to support dynamic switching between S-TRP and M-TRP PUSCH repetition.   Proposal 3-6:   * Support single CG configuration for repetitions towards M-TRP. * Same mapping pattern as dynamic grant can be applied to the mapping between different beams and repetitions with CG. |
| Nokia/NSB | Proposal 21: For single-DCI multi-TRP PUSCH repetition operation, indicate two SRIs separately by extending the SRI field (when needed) for both codebook-based and non-codebook-based UL modes.  Proposal 22: For single-DCI multi-TRP PUSCH repetition with codebook-based mode, indicate two TPMIs by extending the ‘precoding information and number of layers’ field.   * FFS whether/how to reduce the number of bits needed to indicate two TPMIs.   Proposal 23: For the multi-TRP PUSCH repetition, wait for RAN4’s reply to the LS regarding the range of beam switching gaps before discussing further the aspects on beam mapping applicability.  Proposal 24: For beam mapping pattern for multi-TRP PUSCH repetition, support configuring more than one beam mapping patterns and selecting a pattern via DCI.   * FFS the details of how to indicate a pattern via DCI.   Proposal 25: For the indication of two TPC commands via UE-specific PDCCH for multi-TRP PUSCH repetition operation, a second TPC field is added in DCI formats 0\_1 / 0\_2.  Proposal 26: For multi-TRP PUSCH repetition, to indicate the PTRS-DMRS association via DCI, down-select between the following options:   * Option 1: keep the PTRS-DMRS association field size to 2 bits and use each bit for indicating the association per TRP. FFS the details on the interpretation of each bit. * Option 2: increase the PTRS-DMRS association field size to 4 bits, and use the existing procedure for indicating the association per TRP.   Proposal 27: Support dynamic switching between multi-TRP PUSCH scheme and single-TRP PUSCH scheme.   * FFS the details of such switching.   Proposal 28: For the multi-TRP CG PUSCH repetition, support using (at least) two CG configurations used for the transmission of the same TB.  Proposal 29: To enable the multi-TRP CG PUSCH repetition operation, down-select among the following alternatives:   * Alt.2-1: Explicit association of at least two configured-grant configurations * Alt.2-2: Implicit association of at least two configured-grant configurations * Alt.2-3: Association of at least two HARQ processes   Proposal 30: For TX beam selection for multi-TRP CG PUSCH, consider UE’s autonomous selection and indication of the UL TX beam.  Proposal 31: Consider the impact of beam switching gap(s) on actual PUSCH repetitions when the multi-TRP PUSCH type B repetition is applied.   * FFS: Required UE behavior when applying required switching gap(s) on actual PUSCH repetition(s).   Proposal 32: Support multi-DCI based multi-TRP PUSCH repetition scheme. |
| TCL Communications | Proposal 11: Multi-DCI based PUSCH should be supported for multi-TRP PUSCH transmission. |
| Qualcomm | Proposal 21: For single-DCI based M-TRP PUSCH repetition schemes, in both cases of codebook-based and non-codebook based PUSCH transmission, two SRI fields are included in the UL DCI corresponding to the two SRS resource sets.  Proposal 22: To enable dynamic switching between single-TRP and multi-TRP as well as dynamic switching between first SRS resource set and second SRS resource set for single-TRP, each SRI field can indicate that no SRS resource(s) is selected from the corresponding SRS resource set by a SRI codepoint.  Proposal 23: Support configuring each “SRI-PUSCH-PowerControl” with a “sri-resource-setId”. When two SRS resource sets are used, the two corresponding SRI fields point to two sets of ULPC parameters.  Proposal 24: For TPC command in DCI formats 0\_1 / 0\_2, if the “closedLoopIndex” values are different, support:   * Option 4: A single TPC field is used in DCI formats 0\_1 / 0\_2 (2 bits), and indicates two TPC values applied to two closedLoopIndex values, respectively (first preference).   + Support a mapping between TPC field codepoints and a pair of TPC commands. * Option 1: A single TPC field is used in DCI formats 0\_1 / 0\_2, and the TPC value applied for both PUCCH beams (second preference).   Proposal 25: For multi-TRP PUSCH repetition, a DCI that includes two SRI fields also includes two “Open-loop power control parameter set indication” fields when configured.   * The first and second “Open-loop power control parameter set indication” fields are associated with the first and second SRI fields, respectively, and power-boosting are separately indicated for the two sets of repetitions.   Proposal 26: Study the impact of multi-TRP PUSCH repetition on PHR reporting:   * UE to assume either the first set of ULPC parameters or the second set of ULPC parameters for calculating the PHR value.   Proposal 27: For indication of two TPMIs for multi-TRP PUSCH repetition, support Option 3:   * The first field “Precoding information and number of layers” is similar to Rel. 15/16, and indicates a first TMPI index and the number of layers for both TMPIs. * The second field only indicates the second TPMI index.   Proposal 28: For inter-repetition frequency hopping with PUSCH repetition Type A or Type B, frequency hopping is performed among the repetitions with the same beam.  Proposal 29: For PTRS-DMRS association in the case of multi-TRP PUSCH repetition Type B (DCI format 0\_1 / 0\_2 is configured with Repetition Type B via RRC parameters pusch-RepTypeIndicatorForDCI-Format0-1 and RepTypeIndicatorForDCI-Format0-2, respectively)   * If the configured value of maxRank>2, a second PTRS-DMRS association field is included in the DCI, which consists of 2 bits and indicates the PTRS-DMRS association for the second set of repetitions. * If the configured value of maxRank=2, the first bit of the existing PTRS-DMRS association field indicates PTRS-DMRS association for the first set of repetitions and the second bit of the field indicates PTRS-DMRS association for the second set of repetitions.   Proposal 30: For multi-TRP PUSCH repetition (with two sets of repetitions), if AP-CSI is requested in the DCI, UE can be configured to multiplex the CSI reports on the first repetition from the first set of repetitions and on the first repetition from the second set of repetitions.   * For Repetition Type B, the CSI reports are multiplexed on the first actual repetition from the first set of repetitions and on the first actual repetition from the second set of repetitions, and the UE expects that both of the two actual repetitions have duration larger than 1 symbol.   Proposal 31: For Type-1 and Type-2 configured-grant multi-TRP PUSCH repetition, support Alt1 (single CG configuration). |

# References

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| --- | --- | --- | --- |
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| 3 | [R1-2100535](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100535.zip) | On multi-TRP enhancements for PDCCH and PUSCH | Fraunhofer IIS, Fraunhofer HHI |
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| 9 | [R1-2100845](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100845.zip) | Considerations on Multi-TRP for PDCCH, PUCCH, PUSCH | Sony |
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| 11 | [R1-2100965](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2100965.zip) | Discussion on Enhancements on Multi-TRP for Uplink Channels | Asia Pacific Telecom, FGI |
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| 13 | [R1-2101033](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2101033.zip) | Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH | CMCC |
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# 7. RAN1 Agreements

## 7.1 PUCCH

### 7.1.1 RAN1 #102-e

**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

### 7.1.2 RAN1 #103-e

**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.

## 7.2 PUSCH

### 7.2.1 RAN1 #102-e

**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**

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.

**Agreement**

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

### 7.2.2 RAN1 #103-e

**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.