3GPP TSG RAN WG1 #102 R1-200xxxx

e-Meeting, August 17th – 28th, 2020

**Agenda item: 8.1.2.1**

**Source:** **Nokia, Nokia Shanghai Bell**

**Title: Summary of AI:8.1.2.1 Enhancements for Multi-TRP URLLC 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*
  2. *Identify and specify QCL/TCI-related enhancements to enable inter-cell multi-TRP operations, assuming multi-DCI based multi-PDSCH reception*
  3. *Evaluate and, if needed, specify beam-management-related enhancements for simultaneous multi-TRP transmission with multi-panel reception*
  4. *Enhancement to support HST-SFN deployment scenario:*
     1. *Identify and specify solution(s) on QCL assumption for DMRS, e.g. multiple QCL assumptions for the same DMRS port(s), targeting DL-only transmission*
     2. *Evaluate and, if the benefit over Rel.16 HST enhancement baseline is demonstrated, specify QCL/QCL-like relation (including applicable type(s) and the associated requirement) between DL and UL signal by reusing the unified TCI framework*

Based on the Chairman guidance, the following discussions is needed,

[102-e-NR-feMIMO-03] Email discussion on enhancements on multi-TRP for PUSCH, PUCCH by 8/28– Keeth (Nokia)

* Prioritize topics to be resolved in RAN1#102-e by 8/19 (EVM should be highest priority)

To start the discussion, the proposals on the reliability and robustness improvements for PUCCH and PUSCH are summarized in this document and several draft FL proposals are listed.

# Proposals for online/offline discussion on PUCCH

The sub-sections below summarize company proposals on multi-TRP based PUCCH related enhancements based on the submitted contributions. Further details can be found in Section 4 where exact company proposal are mentioned.

## 2.1 Repetition scheme for PUCCH

In the company contributions that discuss the details of PUCCH transmission schemes for multi-TRP, a majority of companies consider PUCCH repetition schemes based on TDM (VIVO, ZTE, InterDigital, QC, Lenovo, Oppo, CMCC, Apple, Xiaomi, LG, Covinda, MediaTek, CATT, AsusTek, DOCOMO, Nokia). There is not much support on FDM/SDM like schemes for PUCCH, thus, such schemes are clearly not the priority in Rel-17 PUCCH reliability enhancements.

Within the proponents of TDMed PUCCH repetition, several companies provide the preference on supporting multi-TRP operation considering both inter-slot and intra-slot PUCCH repetition (VIVO, Intel, Spreadtrum, Ericsson, QC, Nokia), and two companies supporting only inter-slot PUCCH repetition (MediaTek, Lenovo). As the number of inputs are limited on inter-slot and intra-slot repetitions, it makes sense to check further views from companies prior to making any conclusion.

**[Draft for offline] Proposal 1:** Support TDMed PUCCH repetition scheme(s) to improve reliability and robustness for PUCCH using multi-TRP and/or multi-panel. Consider TDMed PUCCH repetition scheme(s) based on,

Alt.1: both inter-slot repetition and intra-slot repetition.

Alt.2: only inter-slot repetition

Please comment preferred changes below. Also indicate the preference on Alt.1 or Alt.2. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| **Company** | **Comments** |
| Apple | We think Rel-17 should support TDM only. But it is too early to decide Alt1 and Alt2. |
| NEC | We are OK with TDM repetition for PUCCH. For Alt1 and Alt2, similar view as Apple, it seems too early to decide. We think both inter-slot and intra-slot repetition should be studied, and if we have to choose, we prefer Alt 1. |
| Lenovo/ Motorola Mobility | Support Alt 2. |
| LG | We are fine with prioritizing inter-slot but would like to keep intra-slot open for further study at this meeting. |
| ZTE | We share the same view with Apple. The first important issue is to **support TDMed beam diversity**. We can further study inter-slot or intra-slot repetition. |
| Spreadtrum | Support the proposal. But we think more discussion is needed before making the choice between Alt.1 and Alt.2. |
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## 2.2 Supported PUCCH formats

TDMed PUCCH repetition is supported in Rel-15 for PUCCH formats 1, 3, and 4 by “*nrofSlots*” provided in “*PUCCH-FormatConfig*”. As highlighted by few companies, it makes sense to extend this PUCCH repetition of PUCCH formats 1, 3, and 4 by also considering multi-TRP operation. Also, few companies (QC, ZTE, VIVO) propose additionally consider PUCCH format 0 and 2 in the multi-TRP PUCCH reliability enhancement. As there are only few companies proposed this, the following alternatives are listed for further considerations.

**[Draft for offline] Proposal 2:** To improve reliability and robustness for PUCCH using multi-TRP and/or multi-panel, consider following PUCCH formats.

Alt.1: All PUCCH formats

Alt.2: Support only PUCCH format 1, 3, and 4.

Please comment preferred changes below. Also indicate the preference on Alt.1 or Alt.2. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | Support Alt1. We think the objective should be to improve reliability and robustness for PUCCH, not for particular PUCCH format(s). |
| NEC | Alt 1. |
| Lenovo/ Motorola Mobility | Alt 1. Same view with Apple. |
| LG | In our understanding, Alt 1 does not mean “support” all formats but “consider” all formats. In this sense, we are fine with Alt 1 with a note that down selection may or may not be needed in further meeting. |
| ZTE | Alt 1 |
| Spreadtrum | Support Alt.1 |
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## 2.3 PUCCH Spatial Relation Info

The existing NR PUCCH repetition scheme uses a single spatial relation associated with the single PUCCH resource is used across all the PUCCH repetitions. Based on a majority of company inputs (ZTE, Lenovo, Ericsson, Apple, LG, QC, CATT, Interdigital, Vivo), this shall be enhanced for multi-TRP based PUCCH transmission, where multiple spatial relations shall be used for PUCCH repetitions towards multiple TRPs. Proponents also suggest investigating further on how the configuration/activation of multiple spatial relation info can be done for enhanced PUCCH repetitions towards multiple TRPs.

As highlighted by few companies (VIVO, Lenovo, DOCOMO, Samsung, QC, Apple, Nokia, ZTE), configuring/activating multiple Spatial Relation Info may also be related to the use of single PUCCH resource or multiple PUCCH resources towards different TRPs. In one alternative, the same PUCCH resource is used for repetitions with multiple spatial relations for a PUCCH resource. In another alternative, different PUCCH resources can be indicated for repetitions. However, many companies are still in the initial phase of evaluations and it makes sense to consider both options for now.

Moreover, few companies discuss details on the mapping patterns between Spatial Relation Info of PUCCH and PUCCH repetitions by considering cyclical mapping and sequential mapping patterns (Lenovo, Spreadtrum, QC). It may be bit early to decide the best mapping patterns, and that could be studied further as proposed below.

**[Draft for offline] Proposal 3:** To enable PUCCH repetition with different beams, support configuring/activating of multiple PUCCH Spatial Relation Info. RAN1 shall further study the following,

* Method of configuration/activation of multiple spatial relation info
* Use of the same PUCCH resource or different PUCCH resource for PUCCH repetitions
* Mapping between PUCCH resource and spatial relation info within a PUCCH repetition bundle

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | In general, there are two options:   * Option 1: configure up to 2 spatial relation for a PUCCH resource * Option 2: configure up to 2 PUCCH resources for a UCI   We think option 2 should be better, which could be more flexible and with less spec impact. |
| NEC | Support the proposal. |
| Lenovo/ Motorola Mobility | We support the proposal in general. We think both two options where one option is configuring up to 2 spatial relation information for a PUCCH resource with repetition and the other option is configuring multiple PUCCH resources for a UCI should be studied. And the two options should be discussed separately. |
| LG | Support. |
| ZTE | Two options can be categorized as Apple/Lenovo suggested. |
| Spreadtrum | Could any company clarify the definition of a PUCCH bundle in the third bullet? In our memory, RAN1 seems not to have such definition. |
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## 2.4 Other proposals

In addition to the main directions mentioned in sections 2.1-2.3, there are other proposals from companies.

On the indication of PUCCH repetitions, several companies think that PUCCH repetitions should be dynamically indicated or investigate further for enhancements (VIVO, Ericsson, ZTE, Lenovo, Intel, Samsung). Ran1 could consider such enhancement compared to Rel-15 like method where the number of repetitions is higher layer configured.

**[Draft for offline] Proposal 4:** 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

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | This is connected with issue 2.3. We can discuss it based on the outcome of 2.3. |
| NEC | Support the proposal. |
| Lenovo/Motorola Mobility | Support Alt 2. Since different PUCCH resources with same format may have different length, the repetition number of different PUCCH resources should be able to be configured or indicated to be different to obtain the same level of reliability. Besides, different types of UCI have different requirement of reliability, therefore, dynamic indication of the number of PUCCH repetitions is needed. |
| LG | Support the proposal. Down selection between the two alts will be done in future meeting. |
| ZTE | Support this proposal |
| Spreadtrum | Support the proposal. Down selection could be done in future meeting. |
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Related to power control mechanisms considering multi-TRP framework, several companies wish to study further on existing power control mechanism vs independent power control mechanisms. At least there is some support (Lenovo, CMCC, Ericsson, DOCOMO, NEC, VIVO, LG, CATT) to discuss power control aspects related to PUCCH repetition towards multiple TRP.

**[Draft for offline] Proposal 5:** For multi-TRP PUCCH transmission, further investigate required power control enhancement.

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | This is connected with issue 2.3. We can discuss it based on the outcome of 2.3. |
| NEC | Support the proposal. |
| Lenovo/Motorola Mobility | Supported. |
| LG | It is worth studying separate TA configuration for 2 TRPs considering different TRP distance. So we support with the following revision.  **Revised proposal 5:** For multi-TRP PUCCH transmission, further investigate required power control and TA enhancement. |
| ZTE | TA enhancement is outside the scope from our view.  For power control, we see the potential issue would be on close loop power control. Then, we suggest a bit change as  **Proposal 5:** For multi-TRP PUCCH transmission, further investigate required power control enhancement, especially for close loop power control |
| Spreadtrum | Fine with the proposal. But the priority should be low. In R16, we also discuss this issue but with no progress, i.e., current mechanism of power control could be applied for multiple PUCCHs towards different TRPs. We have not seen the essential difference between R16 and R17 on multiple PUCCH transmission towards multiple TRPs, from the perspective of power control. |
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## 2.5 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 can be discussed in a later stage once the basic framework is agreed. Please see the full list of company contribution proposals in Section 4. If companies wish to bring any additional aspects related to PUCCH during RAN1 #102-e, please comment below.

Please indicate any other high priority items that companies wish to discuss in RAN1#102-e. Please note that detailed technical proposals may not be possible to agree, thus, keep your proposal in high-level.

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| Company | Comments |
| Apple | Are we going to endorse the EVM we have discussed? |
| LG | We think non-repetition PUCCH transmission scheme from MTRP is a potential candidate scheme. For example, 10 symbol PUCCH is scheduled and 1st to 5th symbols are transmitted to TRP 1 and the remains are to TRP 2.   * Proposal: Consider TDM based single PUCCH scheme without repetition as a potential candidate MTRP scheme. |
| ZTE | Similar view with LG. Beam per hop should be prioritized. |
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# Proposals for online/offline discussion on PUSCH

## 3.1 Single DCI vs multi-DCI PUSCH

Companies provided various inputs on their preferences for supporting DG PUSCH reliability enhancements based on single DCI and multi-DCI based PUSCH repetitions. Support of single DCI based PUSCH repetitions in Rel-17 seems to have more support by the companies (VIVO, Futurewei, ZTE, CATT, Apple, LG, DOCOMO, QC, Nokia, Samsung) compared to the multi-DCI based PUSCH repetitions (VIVO, Futurewei, ZTE, Samsung CMCC, LG (2nd preference), QC (2nd preference), DOCOMO). Even though companies wish to study/support multi-DCI based PUSCH enhancements, the majority wishes to discuss the design based single DCI based approach. Therefore, RAN1 could start agreeing to the PUSCH reliability enhancements shall be based on single DCI approach and also keep the multi-DCI approach open due to the interest of companies.

**[Draft for offline] Proposal 6:** 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.

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| **Company** | **Comments** |
| Apple | We think one scheme should be enough. As single-DCI is used for PDSCH, we think it should be good to support single-DCI only. |
| NEC | Support the proposal. |
| Lenovo/Motorola Mobility | We think both of single DCI based PUSCH transmission and multiple DCI based PUSCH transmission should be studied while the single DCI based PUSCH transmission has a higher priority. |
| LG | We don’t prefer prioritization as it is written. Considering many scheduling parameters such as TPMI/TPC/SRI needs to be configured separately M-DCI also provides a good starting point.  **Revised proposal 6:** For M-TRP PUSCH reliability enhancement, consider single/multiple DCI based PUSCH transmission/repetition scheme(s) |
| ZTE | Fine with the proposal in principle. But we also support MDCI based enhancement. |
| Spreadtrum | Support the proposal |
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## 3.2 Repetition scheme for PUSCH

In the company contributions that discuss the details of PUSCH transmission schemes for multi-TRP, a majority of companies consider PUSCH repetition schemes based on TDM (FutureWei, Vivo, ZTE, Fujitsu, Mtek, Fraunhofer, Lenovo, Oppo, Spreadtrum, Ericsson, Apple, Sharp, LG, Covinda, Asia pacific Telecom, Docomo, QC, Nokia, Xiaomi, AsusTek). Similar to the PUCCH scenario, there is not much support on FDM/SDM like schemes for PUSCH.

Within the proponents of TDMed PUSCH repetition, several companies (Vivo, MediaTek, Intel, Oppo, Spreadtrum, Ericsson, Sharp, LG, QC, Nokia) provide the preference on supporting multi-TRP operation considering both PUSCH repetition Type A and Type B that defined in Rel-16 eURLLC. There are some other views, e.g. supporting only PUSCH repetition Type B (Fujitsu), but not in line with the majority view.

Based on this, it makes sense to agree on the following such that scope is clear for PUSCH reliability enhancements with multi-TRP.

**[Draft for offline] Proposal 7:** 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.

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| **Company** | **Comments** |
| Apple | We suggest changing “TDMed” into “only TDMed”. Other multiplexing schemes should be out of Rel-17 scope. |
| NEC | Support the proposal. |
| Lenovo/Motorola Mobility | Agree with Apple. |
| LG | Firstly, Proposal 6 and 7 should be decoupled so that transmission scheme can be discussed regardless of number of DCI.  Secondly, if we add “only” as Apple suggested, it may cause misunderstanding such that other TDM based MTRP PUSCH schemes are excluded such as MTRP PUSCH scheme without repetition in which, for example, 10 symbol PUSCH is scheduled and 1st to 5th symbols are transmitted through beam/panel toward TRP 1 and the remains are through beam/panel toward TRP 2.  So, our revised proposal as follows:  **Revised proposal 7:** 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 * support TDM based scheme only * consider PUSCH scheme without repetition |
| ZTE | Support the proposal. |
| Spreadtrum | Support the proposal |
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## 3.3 PUSCH Spatial Relation Info

As highlighted by few companies (Lenovo, Ericsson, Apple, LG, QC, CATT, Interdigital, VIVO, Apple), in order to support PUSCH transmission with repetition towards multiple TRPs, multiple UL beams shall be indicated in the DCI. When introducing such enhancement, few proponents (Ericsson, Apple, QC) mentioned the interest of considering both codebook and non-codebook based PUSCH transmission. Moreover, for single DCI based M-TRP PUSCH repetition schemes, several companies (ZTE, QC, Fraunhofer IIS/HHI, Lenovo, Ericsson, Apple, DOCOMO) suggest other enhancements on TPMI/power control parameters. There are also some discussions on the mapping patterns for spatial relation info and PUSCH repetitions (Intel, Fraunhofer, Lenovo, Spreadtrum), and exact details require further investigation.

**[Draft for offline] Proposal 8**: To support single DCI based M-TRP PUSCH repetition scheme(s), at least two spatial relation information is supported. RAN1 shall further study the details considering,

* Codebook based and non-codebook based PUSCH
* Enhancements on TPMI/power control parameters/any other
* Mapping between PUSCH repetitions and spatial relation info

Please comment the necessity and preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | There is no spatial relation info for PUSCH, but we use SRI. From discussion purpose, we think we can use the term “beam”. Further, we think it should be “up to two” instead of “at least two”. Therefore, we suggest the following changes:  “To support single DCI based M-TRP PUSCH repetition scheme(s), up to two beams is supported. RAN1 shall further study the details considering,   * Codebook based and non-codebook based PUSCH * Enhancements on SRI/TPMI/power control parameters/any other * Mapping between PUSCH repetitions and SRI(s)” |
| NEC | We are OK with the updated proposal from Apple. |
| Lenovo/Motorola Mobility | Supported. |
| LG | Proposal 6 and 8 should be decoupled and different TA configuration also needs to be studied.  **Revised proposal 8:**  “To support ~~single DCI based~~ M-TRP PUSCH repetition scheme(s), up to two beams is supported. RAN1 shall further study the details considering,   * Codebook based and non-codebook based PUSCH * Enhancements on TA/SRI/TPMI/power control parameters/any other * Mapping between PUSCH repetitions and SRI(s)” |
| ZTE | Support in principle. |
| Spreadtrum | Support the proposal in principle |
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## 3.4 Other proposals

In addition to the main directions mentioned in sections 3.1-3.3, there are other proposals from companies.

On the support for configured grant PUSCH, several companies (Apple, QC, Nokia, TCL) also thinks that it is important to support both DG PUSCH and CG PUSCH with multi-TRP operation. From the FL perspective, investigating further on CG PUSCH may be challenging due to the workload of the WI, and could be considered if majority of companies support this.

**[Draft for offline] Proposal 9:** Further study M-TRP CG PUSCH reliability enhancements in Rel-17.

Please comment preferred changes below. Please do not edit the draft proposal above and suggest your modification (if any) in the comments.

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| Company | Comments |
| Apple | We are fine with the proposal. We do not see a reason to deprioritize CG-PUSCH. |
| NEC | Support the proposal. |
| Lenovo/Motorola Mobility | Supported. |
| LG | Support |
| ZTE | Support |
| Spreadtrum | Support |
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## 3.5 Additional high priority proposals

Other proposals are not yet included as the main intention of this discussion is agree on the basic framework for further discussion. Please see the full list of company contribution proposals in Section 4. If companies wish to bring any additional aspects related to PUSCH during RAN1 #102-e, please comment below.

Please indicate any other high priority items that companies wish to discuss in RAN1#102-e. Please note that detailed technical proposals may not be possible to agree, thus, keep your suggestion in high-level.

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| Company | Comments |
| Apple | Are we going to endorse the EVM we have discussed? |
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# Summary of Technical proposals

## 4.1 Common for PUCCH and PUSCH

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| Company | Proposals |
| FutureWei | Proposal 1: For multi-TRP non-PDSCH enhancement, clarify the scenario and key assumptions on time/frequency synchronization, backhaul, and M-TRP signal delay spread.  Proposal 5: 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 3: Rel-17 UL enhancements enable spatial filter selection for repetitions per TRP.  Proposal 4: Introduce solutions to enable efficient panel activation and selection for UL transmission.  Proposal 5: Rel-17 enhancements should be flexible enough to support use cases with simultaneous and non-simultaneous transmissions by multi-panel UEs. |
| Sony | Proposal 3: Specify the UE capability whether the UE can transmit simultaneously two PUSCHs/PUCCHs from different antenna panels.  Proposal 4: Specify the UE capability for following.   Total number of antenna panels   Number antenna panel which can transmit simultaneously   Antenna panel direction information |
| MediaTek | Proposal 5: In R17, only TDM-based multi-TRP is specified for PUSCH/PUCCH. |
| China Telecom | Proposal 2: Panel selection and/or joint UL transmission across different panels can be considered for PUSCH & PUCCH enhancement using multi-TRP and/or multi-panel. |
| NEC | Proposal 3: For PUCCH/PUSCH repetition based on multi-TRP, configurations such as beam related parameters, power control parameters should be enhanced. |
| CATT | Proposal 7: At least TDM based approaches can be considered for UL channel enhancement with M-TRP.  Proposal 8: For TDM schemes of PUSCH/PUCCH with M-TRP, the extension of SRS/spatialrelationinfo indication/configuration and resource allocation need further discussion.  Proposal 9: For the UE supporting simultaneous transmission of multiple beams, SDM based repetition scheme can also be considered to improve the robustness and reliability against the blockage with lower latency. |
| Samsung | Proposal 6. Support multi-TRP based PUCCH/PUSCH repetition by using single-DCI based framework as a starting point. |
| Xiaomi | Proposal 3: TDM schemes for PUCCH/PUSCH repetition is much more preferred. |
| Asia pacific Telecom | Proposal 3: Study whether to introduce indication of multiple sets of transmit parameters for repetitive UL transmission in multi-TRP scenario.  Proposal 4: RAN1 to study procedural impact for inter-panel beam switch. |
| AsusTek | Proposal: TDM repetition scheme is suggested as a starting point for M-TRP enhancement for PDCCH, PUSCH, PUCCH. |

## 4.2 PUCCH

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| Company | Proposals |
| FutureWei | Proposal 2: For PUCCH enhancement, the following may be considered:  - Extend Rel-16 enhancement of PUCCH with ACK/NACK to PUCCH with CSI  - Study repeated ACK/NACK transmissions to one or both TRPs  - Study the feasibility of soft combining / joint reception |
| Vivo | Proposal 8: Support PUCCH repetitions for all PUCCH formats and both inter/intra-slot PUCCH repetition.  Proposal 9: Determination of PUCCH resources for repetitions, signaling of number of PUCCH repetitions should be studied.  Proposal 10: Specify the configuration, activation of spatial relations of PUCCH resources for PUCCH repetitions.  Proposal 11: For PUCCH transmission in MTRP, support independent power controls for a single PUCCH transmission and PUCCH repetitions to different TRPs. |
| ZTE | Proposal 3: Support repetition with beam diversity for all PUCCH formats.  Proposal 4: Support dynamical indication of the number of PUCCH repetitions.  Proposal 5: Multiple beams can be configured to one PUCCH resource, and beam switching can be supported among PUCCH repetitions or PUCCH hops. |
| Fujitsu | Proposal 1: In terms of PUCCH multi-TRP enhancement, the following PUCCH format are preferred for further study   PUCCH format 0   PUCCH format 1   PUCCH format 3 |
| MediaTek | Proposal 7: Inter-slot PUCCH repetition can be reused, where each slot/repetition can target a specific TRP.  Proposal 8: The different modes of frequency hopping can be a starting point for TDM-based multi-TRP.  Proposal 9: Take UCI multiplexing into account when designing multi-TRP operation for PUCCH. |
| Lenovo/Motorola Mobility | Proposal 8: PUCCH repetition with multiple beams should support TDM scheme only.  Proposal 9: The spatial relation of PUCCH should be enhanced to include multiple TX beams activated with MAC-CE.  Proposal 10: Flexible number of repetition of PUCCH resource should be supported.  Proposal 11: Cyclical mapping pattern and sequential mapping pattern should be supported in R17 PUCCH repetition.  Proposal 12: Power control mechanism should support PUCCH repetition with multiple spatial relations.  Proposal 13: The inter-slot frequency hopping for PUCCH repetition should be used to obtain the frequency diversity between UE and all TRPs in R17.  Proposal 14: Support a UCI transmitted in multiple PUCCH resources to increase the reliability and robustness of UCI transmission. How to indicate the multiple PUCCH resources can be further studied. |
| Intel | Proposal-14: Consider both slot-level and sub-slot level multi-TCI PUCCH repetitions  Proposal-15: Consider some level of dynamic control of PUCCH repetition factor and switching between 1-TRP and 2-TRP repetitions  Proposal-16: Consider PUCCH DMRS sequence to be cycled in consecutive repetitions in a TRP specific manner |
| Oppo | Proposal 3: Support repetition of PUCCH via multiple TRPs in TDM manner in Rel-17.  Proposal 4: Specify the mapping pattern between spatial relations of PUCCH and PUCCH repetitions. |
| Samsung | Proposal 7. Support the use of multiple PUCCH resources for multi-TRP based PUCCH repetition. |
| CMCC | Proposal 3: TDM scheme could be considered for PUCCH repetition with SpatialRelationInfo and power control related enhancements. |
| Spreadtrum | Proposal 6: Support both intra-slot and inter-slot PUCCH repetition for multi-TRP operation  Proposal 7: For PUCCH beam diversity enhancement of multi-TRP operation,  - Support at least one of the following options for PUCCH repetition with two different spatial relations.   option1: one PUCCH resource can be associated with two spatial relations   oprion2: the UE can be indicated with two PUCCH resources simultaneously, each with a different spatial relation.  - Support both cyclical mapping order and sequential mapping order. |
| Ericsson | Proposal 10: Dynamic switching between single-TRP based PUCCH and multi-TRP based PUCCH should be considered as part of PUCCH multi-TRP enhancements depending.  Proposal 11: For PUCCH multi-TRP enhancements, how to activate/associate multiple spatial relations for a PUCCH resource needs to be considered in NR Rel-17 feMIMO WI.  Proposal 12: For PUCCH multi-TRP enhancements, how to configure/indicate the number of repetitions for PUCCH needs to be further discussed/considered in NR Rel-17 feMIMO WI.  Proposal 13: For PUCCH multi-TRP enhancements, consider power control enhancements related to different close loops and associated TPC commands targeting different TRPs.  Proposal 14: For PUCCH multi-TRP enhancements, consider intra-slot PUCCH repetitions for formats 1, 3 and 4 in NR Rel-17 feMIMO WI. |
| Apple | Proposal 3-1: For PUCCH reliability enhancement, only TDMed based PUCCH repetition multiplexing could be considered.  Proposal 3-2: Support to transmit UCI over PUCCH by indicating up to 2 spatial relation.  Proposal 3-3: Compared to indicate 2 spatial relation for a PUCCH resource, it is slightly preferred to indicate 2 PUCCH resources in non-orthogonal symbols for a UCI transmission. |
| Xiaomi | Proposal 4: Consider to reuse the agreement on TDM PUCCH resources for PUCCH repetition in Rel-16. |
| LG | Proposal 9: For MTRP PUCCH transmission, at least TA, power control parameters and spatial relation RS should be configured separately for different transmission occasion.  Proposal 10: Extend Rel-15 TDM based PUCCH repetition scheme for MTRP PUCCH enhancement.  Proposal 11: TDM based single PUCCH scheme can be considered for both low latency and high reliability, additionally. |
| Covinda Wireless | Proposal 3: PUCCH transmission to two TRPs is supported.  Proposal 6: Only TDM is supported for PUCCH multi-TRP repetition. |
| NTT DOCOMO | Proposal 3:   For PUCCH repetition over multiple TRPs, following options can be considered:   * Option 1: the same PUCCH resource is used for repetitions with multiple spatial relations for a PUCCH resource. * Option 2: different PUCCH resources can be indicated for repetitions.    For PUCCH repetition over multiple TRPs, enhancement on TPC command for PUCCH can be considered. |
| Qualcomm | Proposal 4: Support extending Rel. 15 inter-slot PUCCH repetition mechanisms to  • Two PUCCH-SpatialRelationInfoId’s  • PUCCH formats 0 and 2 in addition to PUCCH formats 1, 3, and 4.  Proposal 5: RAN1 should study pros and cons of the following two alternatives before deciding how to enable intra-slot multi-beam PUCCH transmission:  • Alternative 1: Reusing intra-slot frequency hopping mechanisms to enable beam-hopping within one PUCCH resource.  • Alternative 2: Allowing PUCCH repetition in two different non-overlapping PUCCH resources in a given slot, where the two PUCCH resources are configured / activated with different beams. |
| Nokia | Proposal 8: PUCCH reliability enhancements can be identified considering the following aspects:  • PUCCH repetition operation across multiple TRPs/beams with a focus on TDM schemes.  • FFS: whether intra-slot repetitions should be considered.  Proposal 9: Study solutions to enable tuning PUCCH resources differently for repeated PUCCH transmissions depending on the associated TRP/beam for each transmission.  Proposal 10: Study enhancements for the robustness of periodic PUCCH resource configurations by exploiting multiple TRPs/beams. |

## 4.3 PUSCH

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| --- | --- |
| Company | Proposals |
| FutureWei | Proposal 3: For M-TRP PUSCH enhancement, support:  - TDM of PUSCH, with single or multiple DCIs to schedule the PUSCH  - Multiple scrambling IDs for M-TRP PUSCH transmissions and link to the higher layer indexes  - URLLC related enhancements via PUSCH |
| Vivo | Proposal 4: Rel-16 URLLC Type A and Type B PUSCH transmission can be starting point for PUSCH reliability enhancement in Rel-17.  Proposal 5: TDM repetition is considered as the major optimization target in Rel-17 MTRP PUSCH repetition enhancement.  Proposal 6: Support M-DCI based PUSCH repetition across M-TRP in Rel-17.  Proposal 7: For S-DCI based PUSCH repetition across M-TRP, further study PUSCH transmission schemes without significantly increasing DCI overhead. |
| ZTE | Proposal 6: TDMed PUSCH repetition with beam diversity should be prioritized.  Proposal 7: Considering both single-DCI and multi-DCI based PUSCH repetition with beam diversity.   * For single-DCI based, SRI and TPMI enhancement need to be studied. * For Muti-DCI based, gNB should let UE know which two DCIs schedule the same TB. |
| Fujitsu | Proposal 2: In terms of PUSCH multi-TRP enhancement, PUSCH repetition type B is preferred for further study |
| MediaTek | Proposal 6: PUSCH repetition types A and B can be reused, where each slot/repetition can target a specific TRP. |
| CATT | Proposal 10: RV sequence should be specified for PUSCH enhancements with M-TRP.  Proposal 11: At least S-DCI based PUSCHs repetitions under MTRP scenario can be considered to improve PUSCH robustness and reliability.  Proposal 12: For UL enhancement with M-TRP, separate power control for each link can be considered. |
| Fraunhofer IIS/HHI | Proposal 3: Specify time domain repetition of PUSCH with two different spatial relation and power control settings to transmit to two TRPs.  Proposal 4: Reuse the cyclic and sequential mapping of TCI-states in Rel. 16 PDSCH for the mapping of spatial relation and pathloss reference RS for PUSCH reliability enhancement with repetition.  Proposal 5: Obtain the pathloss reference RS and the spatial relation information with respect to the TRPs from SRI-PUSCH-PowerControl IDs or PUSCH-PathlossReferenceRS IDs and down-selected PDSCH TCI-states, respectively. |
| Lenovo/Motorola Mobility | Proposal 15: PUSCH repetition with multiple beams should only support TDM scheme.  Proposal 16: To support PUSCH repetition with multiple beams, multiple spatial relation information should be supported.  Proposal 17: TDRA field should indicate the number of PUSCH repetition in R17.  Proposal 18: Cyclical mapping pattern and sequential mapping pattern should be supported in R17 PUSCH repetition.  Proposal 19: How to apply the beam mapping pattern for PUSCH repetition Type B should be further studied in R17.  Proposal 20: The power control of a PUSCH repetition with multiple spatial relations should include multiple sets of power control parameters.  Proposal 21: The inter-slot frequency hopping and the inter-repetition frequency hopping for R17 PUSCH repetition should be able to obtain the frequency diversity between UE and all TRPs. |
| Intel | Proposal-9: Multi-TRP PUSCH repetition should apply to both Type A and Type B mapping up to rank-2 transmissions  Proposal-10: For Type B mapping, consider whether TCI state to PUSCH mapping should be performed before or after PUSCH segmentation  Proposal-11: Allow dynamic switching between 1-TRP repetition and 2-TRP repetitions for PUSCH  Proposal-12: Consider DMRS sequence to be cycled in consecutive repetitions in a TRP specific manner |
| Oppo | Proposal 5: Support PUSCH repetition via multiple TRPs in TDM manner with Rel-16 PUSCH for eURLLC as starting point. |
| Samsung | Proposal 8. Support multi-DCI based multi-TRP PUSCH repetition scheme for flexible resource allocation across repetitions. |
| CMCC | Proposal 4: Multi-DCI based PUSCH scheduling could be considered for multi-TRP URLLC PDSCH transmission. |
| Spreadtrum | Proposal 2: For multi-TRP operation, PUSCH repetition in time domain should be prioritized.  Proposal 3: The extension of R16 PUSCH repetition schemes to multi-TRP scenario should be as the starting point.  Proposal 5: For PUSCH beam diversity enhancement of multi-TRP operation,  - Support at least one of the following options of the association between spatial relations and transmission occasion for PUSCH repetition type B:   option1: each spatial relation applied to each actual PUSCH transmission   option2: each spatial relation applied to each nominal PUSCH transmission  - Support both cyclical mapping order and sequential mapping order. |
| Ericsson | Proposal 6 : Consider PUSCH multi-TRP enhancements for PUSCH repetition types A and B; PUSCH multi-TRP enhancements relying on simultaneous transmission are deprioritized in Rel-17 feMIMO.  Proposal 7 : Dynamic switching between single-TRP based PUSCH and multi-TRP based PUSCH should be considered as part of PUSCH multi-TRP enhancements.  Proposal 8 : Consider PUSCH Multi-TRP enhancements for both codebook based and non-codebook based PUSCH in NR Rel-17.  Proposal 9: For PUSCH multi-TRP enhancements, different power control close loops for different TRPs are to be considered in NR Rel-17. |
| Huawei | Proposal 2: For UL non-codebook based PUSCH transmission, the CSI-RS configuration should be enhanced to enable multi-TRP based reception. |
| Apple | Proposal 4-1: For PUSCH reliability enhancement, only TDMed based multiplexing should be considered.  Proposal 4-2: PUSCH reliability enhancement should support the enhancement of DG-PUSCH, CG-PUSCH and Msg3/MsgA PUSCH.  Proposal 4-3: PUSCH reliability enhancement should support enhancement for both codebook based transmission scheme and non-codebook based transmission scheme.  Proposal 4-4: The starting point should consider up to 2 beams/precoders indicated for PUSCH repetitions.  Proposal 4-5: To improve the PUSCH reliability, support gNB to indicate 2 SRIs/TPMIs based on single-DCI operation. |
| Sharp | Proposal 2: PUSCH repetition mechanism specified in Rel-16 URLLC should be reused.  Proposal 3: For multi-TRP PUSCH transmission, TDM scheme is the baseline. |
| LG | Proposal 5: For MTRP PUSCH transmission, at least TA, power control parameters, PMI and spatial relation RS should be configured separately for different transmission occasion.  Proposal 6: Extend Rel-15/16 TDM based PUSCH repetition scheme for MTRP PUSCH enhancement.  Proposal 7: TDM based single PUSCH scheme can be considered, additionally.  Proposal 8: Support S-DCI based MTRP PUSCH transmission and M-DCI based MTRP PUSCH transmission can be additionally considered. |
| Covinda Wireless | Proposal 4: Transmission of a TB on PUSCH to two TRPs is supported.  Proposal 7: Only TDM is supported for PUSCH multi-TRP repetition. |
| Asia Pacific Telecom | Proposal 2: Study how to apply TDM schemes (e.g., introduce a new configuration or apply single transmission layer based PUSCH repetitions in NR Rel-15 and NR Rel-16 as baseline) for multi-TRP/panel based PUSCH repetitions. |
| NTT DOCOMO | Proposal 2:   To support PUSCH repetition over MTRPs, both single-DCI based and multi-DCI based MTRP transmission can be studied.   For single-DCI based MTRP PUSCH transmission, enhancements on SRI and TPC command indications can be considered. |
| Qualcomm | Proposal 6: Support extending PUSCH repetition Type A and Type B to repetitions with different sets of UL beams / different sets of transmission parameters for codebook based UL transmission and non-codebook based UL transmission including  • Indication of two sets of power control parameters (by enhancing SRI signalling in the DCI)  • Indication of two spatial relation Info’s (by enhancing SRI signalling in the DCI)  • Indication of two TPMIs for codebook based UL transmission (by enhancing “Precoding information and number of layers” signaling in the DCI)  Proposal 7: Enhancements for reliability and robustness of PUSCH should be extended to the case of configured grant for both cases of Type 1 and Type 2 configured grant.  Proposal 8: RAN1 should study if and how multi-DCI based multi-PUSCH transmission can be optimized to enhance the flexibility and performance of PUSCH.  • Compared to single-DCI based approach, multi-DCI based approach has lower priority. |
| Nokia | Proposal 11: PUSCH reliability enhancements can be identified considering the following aspects:  • PUSCH repetition operations across multiple TRPs/beams with a focus on TDM schemes  • PUSCH repetition Type A and Type B can be considered.  • For DG PUSCH, focus on a single-DCI design.  Proposal 12: Study low overhead mechanisms for the TX beam selection for multi-TRP CG PUSCH. |
| TCL | Proposal 1: Configured grant PUSCH should be supported and identified as an essential feature in multi-DCI based multi-TRP in Rel-17.  Proposal 2: Association between configured grant PUSCH and TRP should be studied in Rel-17.  Proposal 3: Out-of-order scheduling for multiple PUSCHs that include configured grant PUSCH should be studied in Rel-17.  Proposal 4: When multiple PUSCHs including configured grant PUSCH collide in multi-DCI based multi-TRP scenario, how to solve the collision problem should be further studied. |

# References

8.1.2.1 Enhancements on Multi-TRP for PDCCH, PUCCH and PUSCH

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