**3GPP TSG RAN WG1 #105-e R1-210xxxx**

**e-Meeting, May 10th – 27th, 2021**

**Agenda item:** 8.8.2

**Source:** Moderator (Qualcomm)

**Title:** FL summary of PUCCH coverage enhancement

**Document for:** Discussion/Decision

# Introduction

In this document, a summary of companies’ proposals for PUCCH coverage enhancement is provided.

# Dynamic PUCCH repetition factor indication

## Scope of dynamic PUCCH repetition factor indication

Regarding whether dynamic PUCCH repetition factor indication should be applied to semi-static PUCCH, there are diverged views based on submitted contribution from companies.

Spreadtrum, QC, ETRI, and Ericsson support dynamic PUCCH repetition factor indication to P/SP PUCCH as well. On the other hand, CATT and LG don’t support dynamic PUCCH repetition factor indication for P/SP PUCCH.

## Options for dynamic PUCCH repetition factor indication

In RAN1 104-e meeting, the following agreements were made regarding dynamic PUCCH repetition factor indication.

Agreements: Down select from the following two options to support dynamic PUCCH repetition factor indication.

* Option 1 (without DCI enhancement): Enhance RRC signaling to allow configuration of PUCCH repetition factor per PUCCH resource. PUCCH repetition factor is implicitly indicated by DCI.
	+ FFS details, e.g., via reusing the “PUCCH resource indicator” field (without increase # bits of it), starting CCE index (when applicable) of DCI, by PDCCH aggregation level, etc.
	+ FFS: RRC signaling enhancement details
* Option 2 (with DCI enhancement): PUCCH repetition factor is explicitly indicated by DCI
	+ e.g., introduce a new field or increase the number of bits of an existing field (e.g., PRI) in DCI for PUCCH repetition factor indication
	+ FFS whether there is a need for RRC update

Based on companies’ contribution, the pros and cons of the three options can be summarized in the below table.

|  |  |  |
| --- | --- | --- |
|  | Pros | Cons |
| Option 1 | Minimum spec change (only has RRC change. NO DCI change)**Applicable to fallback DCI** | Less flexibility  |
| Option 2 | Maximal flexibilityLarger spec impact (Need DCI change. May need RRC change depends on detailed solution of option 2) | Increased DCI size/new DCI field**Not applicable to fallback DCI** |

According to companies’ contributions, the split of supporting companies for option 1 and option 2 are as follows.

* 19 Companies supporting option 1: Huawei/HiSi, VIVO, CT (2nd preference), CATT (1st preference), CMCC(1st preference), IDC, Intel, Apple, Panasonic, Spreadtrum, ETRI, Xiaomi, Sharp, Ericsson, Docomo, Lenovo/Moto, LG?
* 9 companies supporting option 2: ZTE, OPPO, CT (1st preference), Samsung, CATT (2nd preference), CMCC (2nd preference), Nokia/NSB, LG?

Both options can work to support dynamic PUCCH repetition indication. Considering that option 2 cannot be used with fallback DCI, which is typical used DCI for coverage limited UE, from technical point of view, option 1 seems better. Furthermore, majority companies support option 1. Therefore, FL recommend the group to take option 1 to move forward.

**FL Proposal 1: Option 1 (as agreed in RAN1 104-e) is adopted to support dynamic PUCCH repetition factor indication.**

Companies are welcome to provide comments to the above proposal in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
|  |  |
|  |  |

# DMRS bundling across PUCCH repetitions

The second objective of this agenda item is to “specify mechanism to support DMRS bundling across PUCCH repetitions.” Under this objective, a few topics are addressed in companies’ contributions. The topics are summarized as below.

## Use cases

In the LS R1-2104119 sent to RAN4, the following use cases were agreed.

For PUCCH repetitions, the following use cases are considered in RAN1. Among the following cases, RAN1 suggest RAN4 to prioritize the study on use case 3, 4a, 4b, and 5b for PUCCH repetitions.

   Use case 1: back-to-back PUCCH repetitions within one slot.

   Use case 2: non-back-to-back PUCCH repetitions within one slot.

‐   Use case 2a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use case 2b: other uplink transmissions in the middle of two PUCCH repetitions

   Use case 3: back-to-back PUCCH repetitions across consecutive slots.

   Use case 4: non-back-to-back PUCCH repetitions across consecutive slots.

‐   Use 4a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use 4b: other uplink transmissions in the middle of two PUCCH repetitions

   Use case 5: PUCCH repetitions across non-consecutive slots.

‐   Use case 5a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use case 5b: other uplink transmissions in the middle of two PUCCH repetitions

Note: RAN1 assumes “back-to-back PUCCH repetitions” has zero gap in-between adjacent PUCCH repetitions.

Note: intervening “other uplink transmissions” can be either on the same component carrier or a different component carrier.

In the contributions submitted to this meeting, there are proposals to further prioritize several use cases for PUCCH repetitions.

ZTE Proposal 2: Support Use case 1 and Use case 3 for joint channel estimation or joint detection of PUCCH repetitions.

* Clarify that Use case 1 includes both PUCCH format 0 and PUCCH format 2.

ZTE Proposal 3: Decide whether to support Use case 2a/4a/5a for PUCCH repetitions depending on RAN4 further discussion.

ZTE Proposal 4: Do not support joint channel estimation for Use case 2b/4b/5b for PUCCH repetitions.

QC Proposal 5: Support the following use cases:

Ÿ   Use case 3: back-to-back PUCCH repetitions across consecutive slots.

Ÿ   Use case 4: non-back-to-back PUCCH repetitions across consecutive slots.

‐   Use 4a: no uplink transmission in the middle of two PUCCH repetitions

VIVO Proposal 2: Optimizations specifically for use case 1 and use case 2 for DMRS bundling for PUCCH repetitions should be avoided.

Given that only three companies discussed this topic in their contribution, FL would like to collect more input from companies before draw a conclusion on this topic. Companies please provide your answers/comment to the following questions.

**FL Question: Should RAN1 prioritize a subset of agreed use cases in RAN1 study? If Yes, should RAN1 prioritize use cases 3, 4a, 4b, and 5b as RAN1 suggested in R1-2104119 for RAN 4 study? If No, what are the use cases RAN1 should prioritize?**

|  |  |
| --- | --- |
| **Company name** | **Answer/comment to the above questions** |
|  |  |
|  |  |

## Signalling mechanism to enable DMRS bundling across PUCCH repetitions

In RAN1 104-e, the following agreements were made.

Agreements:

Subject to the prerequisites of DMRS bundling for PUCCH repetitions, support enabling PUCCH repetitions with DMRS bundling via RRC configuration.

* FFS: the configuration is per UE or per PUCCH resource.
* FFS: whether additional dynamic signaling is needed to enable/disable PUCCH repetitions with DMRS bundling
* FFS: necessity of additional signaling/configuration of DMRS bundling duration/window and associated size

Based on the above agreement. There are three open issues for further study.

Question 1: the RRC configuration to enable PUCCH repetition is per UE or per PUCCH resource?

Companies’ views submitted in the contributions are the following:

* Per UE: HW/HiSi, CATT, ETRI, Samsung, Xiaomi, Nokia
* Per PUCCH resource: QC, Apple, NEC, DCM

Question 2: whether additional dynamic signaling is needed to enable/disable PUCCH repetitions with DMRS bundling?

Companies’ views submitted in the contributions are the following:

* Not needed: CT, HW/HiSi, Nokia
* Needed: Xiaomi, Interdigital

Regarding the details of dynamic signaling, there are a few proposals.

Interdigital Proposal 3: Support a grant-type dependent index which indicates to the UE which PUCCH repetitions to bundle

Xiaomi Proposal 4: Multiple semi-static DMRS bundling configurations can be configured by RRC for per UE, and one of the configurations is activated through DCI signaling.

Question 3: Whether/how to design additional signaling/configuration of DMRS bundling duration/window and associated size?

The following proposals are submitted in contributions.

HW Proposal 5: A common design for both PUCCH and PUSCH is supported, regarding to the signaling/configuration of DMRS bundling duration/window and associated size.

ZTE Proposal 5: Specify a time domain window for PUCCH repetition.

* A UE reports a same time domain window size for PUSCH and PUCCH.

CMCC Proposal 3:

* For the design of frequency hopping, the DMRS bundling of PUSCH should could be the starting point of PUCCH.

QC Proposal 6: Similar to PUSCH joint channel estimation, RAN1 specifies time domain window(s) over which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements.

* Support multiple non-overlapping time domain windows for joint channel estimation over PUCCH repetitions.
* Window is determined based on semi-static slot format configuration.
* Window duration is in unit of physical slots.
* All windows have the same window duration.
* FFS: determine start of a window.

CT Proposal 5: For joint channel estimation, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.

Interdigital Proposal 4: For a hopping pattern that includes all of K repetitions in a hop, configure one time window matching the duration of a hop.

Intel Proposal 2

* A time domain window is specified for joint channel estimation over multiple PUCCHs, during which a UE is expected to maintain power consistency and phase continuity.
	+ The time domain window is defined based on the number of repetitions or slots.
	+ The time domain window may be configured by higher layers.
	+ When inter-slot frequency hopping with inter-slot bundling is applied, the time domain window is determined by the bundle size.
* Within the time domain window, UE needs to maintain same Tx power, precoder and frequency resource for joint channel estimation over multiple PUCCHs.

Panasonic Proposal 2: Specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements.

Panasonic Proposal 3: For the indication of the length of time domain window, enhance RRC signaling to allow configuration of the length of time domain window per PUCCH resource. Enabling/disabling and the length of time domain window are indicated via reusing PUCCH resource indicator field. PUCCH resource indicator field should be extended for further flexibility.

LG Proposal 3: We should revisit DMRS bundling across PUCCH repetitions after joint channel estimation for PUSCH

Sharp Proposal 4: For DMRS bundling, a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements should be adopted.

DCM Proposal 2: The same mechanism of DMRS bundling across repetitions discussed in PUSCH enhancement can be applied for PUCCH enhancement.

Lenovo Proposal 2: For supporting joint channel estimation with DM-RS bundling across multiple PUCCHs for coverage enhancements in NR Rel-17, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.

Nokia Proposal 4. No additional semi-static/dynamic signalling is introduced for configuring DMRS bundling window and associated size.

For DMRS bundling for PUCCH repetitions, majority companies support to define a time domain window, similar to what was agreed for PUSCH repetition. Therefore, the following FL proposal is made.

**FL proposal 2: For DMRS bundling for PUCCH repetitions, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.**

* **Strive for common signaling mechanism of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.**
* **FFS whether use the same time domain window size for PUCCH repetitions and PUSCH repetitions.**

Companies are welcome to provide comments to the above proposal in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
|  |  |
|  |  |

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 104e, the following agreements were made.

Agreements: Subject to the prerequisite of DMRS bundling for PUCCH repetitions, enhance inter-slot frequency hopping pattern for PUCCH repetitions with DMRS bundling.

* FFS: details in inter-slot frequency hopping pattern enhancement, e.g., additional frequency hopping patterns than Rel-16.
* Strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible

In companies’ contributions, the following proposals are made regarding to the topic of inter slot frequency hopping enhancement with DMRS bundling.

HW Proposal 2: Inter-slot frequency hopping pattern with inter-slot bundling can be considered for the inter-slot frequency hopping pattern enhancement.

ZTE Proposal 6: Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation among repetitions per bundle is supported.

Spreadtrum: For example, to facilitate joint channel estimation, the repetitions of PUCCH in consecutive UL slots can be mapped to the same hop as many as possible.

CATT Proposal 6: Hopping interval of the enhanced inter-slot frequency hopping pattern can be equal to the DMRS bundling window duration/size.

QC Proposal 8: When the PUCCH repetition is enabled, the frequency hop for PUCCH repetition transmission is determined based on the repetition count for each PUCCH transmission occasion.

QC Proposal 9: When inter-slot frequency hopping is configured with DMRS bundling, all PUCCH transmissions in a single time domain DMRS bundling window belong to the same hop.

OPPO Proposal 4: For enhancement, the PUCCH repetition with frequency hopping can introduce 2 bundles of slots. Each bundle of slots can be transmitted in different PRBs.

Interdigital Proposal 5: Support a hopping pattern with DMRS bundling where during one hop, all of K repetitions are included.

Intel Proposal 3

* Inter-slot frequency hopping with inter-slot bundling is supported for PUCCH enhancement.
	+ The bundle size may be configured higher layers or determined based on the number of repetitions.

Apple Proposal 3: Specify the inter-slot frequency hopping pattern to enable the conjunction operation of repetition, frequency hopping and joint channel estimation.

Panasonic Proposal 4: One or more lengths of time domain windows are configured to be jointly used with inter-slot frequency hopping / precoder cycling.

* Each of the one or more lengths of time domain windows is used for the same frequency allocation in inter-slot frequency hopping procedure.

ETRI: Proposal : If inter-slot frequency hopping is enabled, then the PUCCH repetition may hop in the middle of slot, depending on the TDD slot pattern and the number of repetitions, and the coherence can be kept in the same split.

Xiaomi: Proposal 3：Introduce configurable additional inter-slot frequency hopping patterns for PUCCH repetitions with DMRS bundling.

DCM Proposal 4: The duration per frequency hop should be implicitly determined by the time domain window, where the duration per frequency hop is equal to a time domain window size for joint channel estimation.

Lenovo Proposal 3: For supporting joint channel estimation with DM-RS bundling across multiple PUCCHs for coverage enhancements in NR Rel-17, support multi-slot frequency hopping and multi-slot DM-RS bundling for joint channel estimation for entire hop:

* Association between frequency hop duration and time-domain window should be supported such that explicit indication of both the frequency hop duration and time-domain window is not needed
	+ Time-domain window size can be equal to the frequency hop duration
* At least hop duration of 2 slots should be supported with DM-RS bundling

Nokia Proposal . For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation:

* RAN1 to specify at least the following frequency hopping approach:
	+ UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive or after an UL transmission with different settings (e.g., in antenna port, occupied PRBs and UL power) than the PUCCH repetitions.

For inter slot frequency hopping with DMRS bundling, majority companies support additional frequency hopping patterns than Rel-16 to allow DMRS bundling within a duration per frequency hopping (a.k.a., time domain hopping interval as defined for PUSCH repetition). Majority companies support to set the bundle size equal to the time domain window size (to keep power consistency and phase coherency).

**FL Proposal 3: For inter slot frequency hopping with DMRS bundling, all PUCCH repetitions in a frequency hopping duration (similar to the time domain hopping interval defined for PUSCH repetition) belong to the same frequency hop.**

* **The frequency hopping duration equals to the size of time domain window where power consistency and phase coherency can be maintained.**

Companies are welcome to provide comments to the above proposal in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
|  |  |
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# Others

There are a few other proposals mentioned in submitted contributions to this agenda. FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 2 and Section 3.

[[R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip)]: The maximum number of repetitions for transmission of PUCCH repetition is 32.

[[R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip)]: The dynamic PUCCH repetition mechanism should be applied to all PUCCH formats and all UCI types including A-CSI.

[[R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip)]: Further study the benefit of gNB estimated inter-slot relative phase correction for PUCCH, addressing how frequency selective such phase corrections would need to be for UEs and/or conditions that do not sufficiently support maintaining inter-slot relative phase.

* Consider operation with and without frequency hopping and with and without transparent transmit diversity.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: For a PUCCH (or PUSCH) repetition with DMRS bundling, only TPC indicated by a unicast DCI is applied, i.e. TPC on GC-DCI 2-2 is ignored.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: Unicast DCI with a TPC command implicitly indicates that DMRS bundling is off, from the occasion that new TPC is applied.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: Specify conditions under which a PUCCH with dynamic indication of repetition number may overlap with another PUCCH repetitions without dynamic indication of repetitions.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: If DMRS bundling is supported, specify conditions under which phase continuity is kept for a PUCCH with DMRS bundling overlapping in one (or more) occasions with a second PUCCH without DMRS bundling.

[[R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip)]: A UE updates the CLPC adjustment state per time domain window.

# References

|  |  |  |
| --- | --- | --- |
| [R1-2104243](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104243.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2104333](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104333.zip) | Discussion on coverage enhancements for PUCCH | ZTE |
| [R1-2104379](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104379.zip) | Discussion on PUCCH enhancements | vivo |
| [R1-2104438](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104438.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2104540](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104540.zip) | Discussion on PUCCH enhancement | CATT |
| [R1-2104628](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104628.zip) | Discussion on PUCCH enhancements | CMCC |
| [R1-2104688](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104688.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2104795](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104795.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2104849](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104849.zip) | Discussion on PUCCH enhancements | China Telecom |
| [R1-2104862](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104862.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2104922](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104922.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2104978](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104978.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2105035](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105035.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip) | PUCCH coverage enhancement | Apple |
| [R1-2105149](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105149.zip) | Discussion on PUCCH enhancement for NR coverage enhancement | Panasonic Corporation |
| [R1-2105224](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105224.zip) | PUCCH enhancements | ETRI |
| [R1-2105239](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105239.zip) | PUCCH enhancements | ETRI |
| [R1-2105257](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105257.zip) | Discussion on PUCCH enhancements | NEC |
| [R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip) | PUCCH enhancements | Samsung |
| [R1-2105360](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105360.zip) | PUCCH enhancements | ETRI |
| [R1-2105491](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105491.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2105578](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105578.zip) | PUCCH coverage enhancement | Xiaomi |
| [R1-2105643](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105643.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip) | PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [R1-2105714](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105714.zip) | PUCCH enhancements | NTT DOCOMO, INC. |
| [R1-2105776](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105776.zip) | Enhancements for PUCCH repetition | Lenovo, Motorola Mobility |
| [R1-2105904](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105904.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |