**3GPP TSG RAN WG1 #106-e R1-210xxxx**

**e-Meeting, August 16th – 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.

Whether to support dynamic PUCCH repetition factor indication to P/SP CSI or SR?

* Support: QC, ETRI, Ericsson
	+ Rationale: The motivation for PUCCH enhancement from the study item phase was for CSI (which is the coverage bottleneck), so dynamic repetition for PUCCH should support at least CSI.
* Not support: HW/HiSi, ZTE, CATT, Panasonic, OPPO
	+ Rationale: As the P/SP CSI payload size is static, gNB can set static repetition factor accordingly.

Whether to support dynamic PUCCH repetition factor indication to HARQ-ACK for SPS PDSCH?

* Support: ZTE, QC, ETRI
	+ Rationale: the same PUCCH repetition faction indication mechanism as for dynamic HARQ-ACK can be reused
* Not support: CATT
	+ Rationale: for semi-static UCI, any repetition parameters of the corresponding PUCCH resource can only be semi-statically configured by RRC.

Companies are welcome to provide comments/views to this topic.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| China Telecom | We think dynamic PUCCH repetition factor indication to P/SP CSI or SR is not support. |
| CMCC | Not support the dynamic PUCCH repetition factor to P/SP CSI or SR.For the Periodic and semi-persistent CSI and SR, the repetition should be based on the RRC configurations. Once the UE needs enhancements for the periodic feedbacks, there is no need to update the repetition factor from time to time. |
| Vivo | No need to discuss. The semi-static PUCCH or P/SP PUCCH is out of scope. |
| Intel  | We do not support dynamic PUCCH repetition factor indication for P/SP CSI or SR and HARQ-ACK for SPS PDSCH. This is semi-static PUCCH resource configuration, where semi-static repettition factor should be used for PUCCH. It is not clear the motivation. |
| Nokia/NSB | In our view, use of dynamic PUCCH repetition factor should be limited to dynamic HARQ-ACK. P/SP reporting, or HARQ-ACK for SPS PDSCH are designed not to require further dynamic adjustments. The whole point of configuring them as P/SP would seem void if this were not the case. Concerning P/SP CSI, indeed its payload size is static, hence gNB can set static repetition factor accordingly. Concerning SPS PDSCH, it should be noted its main use is in the context of URLLC, for which dynamic signaling does not seem suitable. |
| Samsung | Do not support dynamic indication of repetitions for semi-static configuration of resources. That can actually be detrimental as, by definition, P/SP UCI is not associated with a DCI format and whatever was indicated for transmission at time A by a DCI format may not be suitable for transmission at time B, C, D, … when there is no DCI format. Relying on existence of regular DCI formats to update repetitions of P/SP UCI is not reasonable. |
| Lenovo, Motorola Mobility | We do not support dynamic indication of repetitions for P/SP CSI or SR |
| Apple | Do not support dynamic indication for P/SP-PUCCH (wasn’t this same topic discussed in FL’s summary in 105-e?!)  |
| Ericsson | We agree that P/SP CSI can get greater coverage by configuring repetition. However, dynamic repetition (regardless of whether it is HARQ-ACK or CSI) is about improving spectral efficiency while maintaining coverage: the gNB selects repetition factor according to current channel conditions. There is no mechanism for repeating aperiodically triggered CSI today, regardless of if it is on PUSCH or PUCCH, and so the next best thing we can do is to dynamically change the repetition factor of P/SP CSI. **Since in our understanding HARQ-ACK is less of a bottleneck than CSI, we don’t see how the intent of the WI is met unless we somehow support dynamic repetition for CSI.**  |

## Dynamic PUCCH repetition factor indication scheme

### Confirm the working assumption

In RAN1 #105e, the following working assumption was agreed.

Working assumption: In Rel-17, for a PUCCH with associated scheduling DCI, support the following for dynamic PUCCH repetition factor indication.

* Enhance RRC signaling to allow configuration of PUCCH repetition factor per PUCCH resource. Reuse Rel-16 PUCCH resource indication mechanism based on “PUCCH resource indicator” (PRI) field and starting CCE index (when applicable based on Rel-16 spec) of DCI to indicate a PUCCH resource and its associated repetition factor.
	+ FFS: RRC signaling enhancement details

Based on the proposals in contributions submitted by companies, majority companies want to confirm the working assumption. However, [**R1-2106905**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip) raised a concern on the working assumption. The concern is that, given a PRI of 3 bits which can indicate 8 resources, if each resource is associated with 4 numbers of repetitions, that effectively only leave a residual 1 PRI bit for PUCCH resource indication.

**FL Question 1: Do you view the issue raise in** [**R1-2106905**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip) **as a critical issue? What is the solution to solve the issue?**

Companies are welcome to provide answer the question in the table below.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| China Telecom | We support to confirm the working assumption. As for the issue raised by Samsung, we think it will limit some flexibility. We are open to discuss it. |
| CMCC | Support to confirm the working assumption. The details could be discussed further.  |
| vivo | Not a critical issue. It is not necessary to include all the 4 repetition numbers in a resource set. NW can properly (re)configure the number of repetitions in PUCCH resource configuration in a PUCCH resource set. |
| Intel | We are fine to confirm the working assumption. The issue mentioned by FL can be alleviated by gNB configuration/scheduling.  |
| Samsung | Either confirm the WA or introduce explicit indication and avoid other complexities that may also not provide as robust solution. |
| Lenovo, Motorola Mobility | We support to confirm the working assumption |
| Apple  | Confirm WA (it is already specified for Set0) |
| Ericsson | The WI can be confirmed. We don’t see a big concern with the loss of PUCCH resource scheduling flexibility, but if that is a critical issue, details such as PRI field size could be discussed. |

### Applicability of dynamic PUCCH repetition factor indication

One discussion point on dynamic PUCCH repetition factor indication is whether apply this feature to all PUCCH format. Based on proposals from contributions submitted by companies, the views are the following.

* Dynamic PUCCH repetition factor indication only applies to PUCCH format 1, 3, 4:
	+ Supported by: Nokia, CATT, Oppo
* Dynamic PUCCH repetition factor indication only applies to all PUCCH formats
	+ Supported by: QC, Ericsson, Panasonic

Based on the agreements made in RAN1 #105e under IIoT/URLLC WI, dynamic PUCCH repetition is applied to short PUCCH format 0 and 2.

Agreement:

* Support sub-slot-based PUCCH repetition for HARQ-ACK based on the Rel.16 PUCCH procedure for slot-based PUCCH applied to sub-slot-based PUCCH.
	+ Note: The intention is to take the Rel.16 slot-based PUCCH by replacing with “sub-slot” appropriately, without further optimization unless necessary.
	+ FFS whether or not there is any restriction for the applicability of sub-slot-based PUCCH repetition for HARQ-ACK
	+ Dynamic repetition indication is supported also for sub-slot-based PUCCH in Rel.17.
		- FFS: If the method to be specified in CovEnh WI for slot-based PUCCH repetition can be directly applied to sub-slot PUCCH or if changes are needed.

Agreement:

* + Support PUCCH repetition for PUCCH formats 0 and 2 at least for sub-slot-based PUCCH repetition.
		- FFS: Support for slot-based PUCCH repetition

Apparently, dynamic repetition factor indication should also be applied to long PUCCH format 1,3,4, as this is the intention anyway for this WI. Furthermore, based on companies’ input in the contributions, majority companies support dynamic repetition factor indication for long PUCCH format 1,3,4.

With the above, FL has the following proposal.

**FL Proposal 1: Support dynamic PUCCH repetition factor indication for all PUCCH formats including format 0, 1, 2, 3, 4.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| China Telecom | Fine with this proposal. |
| CMCC | Currently we support the enhancement to PUCCH format 1,3,4. Format 0 and 2 needs more discussion. |
| vivo | Support the FL proposal. |
| Intel | We support the FL proposal 1. Based on the agreement from eURLLC, support of dynamic indication for PUCCH format 0 and 2 should be considered.  |
| Nokia/NSB | Support. |
| Samsung | No need to support repetitions for PUCCH formats 0 and 2 for coverage enhancements.  |
| Lenovo, Motorola Mobility | We support the FL proposal |
| Apple | Same view as Samsung. Repetition for short PUUCH is not needed , gNB can just indicate a long format. |
| Ericsson | Support the FL proposal, and share FL’s and Intel’s understanding that URLLC has agreed to support dynamic repetition of formats 0 and 2. |

### Interaction between dynamic repetition factor indication and semi-static repetition factor indication

When both the legacy (semi-static) PUCCH repetition factor nrofSlots and the new (dynamic) PUCCH repetition factor are configured to a UE, one discussion point is how does UE handle the interaction between these two features.

A few companies submitted proposals to address this issue. The proposals are listed as below.

[R1-2106658](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106658.zip): For interaction between the RRC configured repetition factor nrofSlots and the dynamically indicated repetition factor for PUCCH, the following procedure applies:

* For a PUCCH format 1, 3 and 4 with associated scheduling DCI, the dynamically indicated PUCCH repetition factor (if configured) applies and overrides the RRC configured repetition factor nrofSlots.
* For a PUCCH format 1, 3 and 4 without associated scheduling DCI, the RRC configured repetition factor nrofSlots applies.

[**R1-2107142**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107142.zip): If both static PUCCH repetition factor and dynamic PUCCH repetition factor are configured to UE, UE should apply dynamic PUCCH repetition factor which is similar to dynamic PUSCH repetition factor overwriting static PUSCH repetition factor.

[**R1-2107551**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107551.zip): It is necessary to discuss the relationship between the PUCCH repetition number indicated dynamically and the PUCCH repetition number indicated in the PUCCH-FormatConfig.

[**R1-2107802**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107802.zip): the number of repetitions $N\_{PUCCH}^{repeat}$ for a PUCCH transmission corresponding to a PUCCH resource and a PUCCH format is determined as:

* + - if the new repetition parameter is configured on the PUCCH resource, $N\_{PUCCH}^{repeat}$ is equal to the new repetition parameter;
		- elseif nrofSlots is configured on the PUCCH format, $N\_{PUCCH}^{repeat}$ is equal to nrofSlots;
		- otherwise, $N\_{PUCCH}^{repeat}=1$.

The proposals are essentially aligned, despite the wording difference among them. Based on the above proposals, A FL proposal is made as below.

**FL Proposal 2: the number of repetitions** $N\_{PUCCH}^{repeat}$ **for a PUCCH transmission corresponding to a PUCCH resource and a PUCCH format is determined as:**

* + - **if a new repetition parameter corresponding to Rel-17 dynamic PUCCH repetition factor indication is configured on the PUCCH resource,** $N\_{PUCCH}^{repeat}$ **is equal to the new repetition parameter;**
		- **elseif nrofSlots is configured on the PUCCH format,** $N\_{PUCCH}^{repeat}$ **is equal to nrofSlots;**
		- **otherwise,** $N\_{PUCCH}^{repeat}=1$**.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CMCC | Support. |
| vivo | Support the FL proposal |
| Intel | We are fine with the proposal 2.  |
| Nokia/NSB | Support |
| Samsung | The proposal can be simplified to just say that DCI indication overrides RRC configuration, if any (as was done for every other proposal on DCI vs. RRC interaction). When DCI indication is not provided, Rel-16 applies. That also avoids unnecessary confusion. |
| Lenovo, Motorola Mobility | We are generally fine with the proposal and also support Samsung’s suggestion |
| Apple | Support |
| Ericsson | Support |

### Number of repetitions allowed

Regarding the number of repetitions allowed to be configured with this feature of dynamic PUCCH repetition indication, a few proposals are proposed, and they are summarized as below.

* [R1-2106905](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip): Support Up to 32 repetitions
* [R1-2107802](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107802.zip), [R1-2107259](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107259.zip): Support 1, 2, 3, 8 repetitions
* [R1-2107259](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107259.zip): Support 16 repetitions
* [R1-2107653](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107653.zip): Support at least up to 8 repetitions

The views are still diverged on this issue. Companies are welcome to provide comments to the issue in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CMCC | The enhancement of PUCCH maximum repetition number is out of the scope.The repetition factor of 2,4,8 should be reused. |
| vivo | We propose to support the repetition number as already defined in Ts 38.331, which is {1,2,4,8}. In our understanding, the objective of dynamic indication of PUCCH repetition does not include extending the maximum number of repetitions for PUCCH. |
| Intel | The existing number of repetitions for PUCCH can be reused.  |
| Nokia/NSB | Evidence from SI did not highlight a coverage shortage such that very large number of repetitions are needed. Given that each doubling is expected to bring ~2-2.5 dB of performance improvement, we do not see a clear need to exceed 8 as maximum configurable number. The set {1, 2, 4, 8} could provide a valid starting point for the discussion. |
| Samsung | Depends on the maximum payload to support. Considering that 8 repetitions were allowed in LTE (and in Rel-15) for 1-2 bits at 15 kHz with 14 symbols, a maximum of 32 repetitions is appropriate (and actually somewhat small) for up to 11 bits, 30 kHz, and less than 14 symbols.  |
| Lenovo, Motorola Mobility | We do not support extending the number of repetition for PUCCH as we don’t think this is within the scope of the WI |
| Ericsson | Agree with comments above that increased repetition was not included in the WI scope and that 2, 4, 8 is probably enough. Furthermore, if additional repetition is considered, this should be at least where coverage is most needed, i.e. CSI. |

### Details of repetition factor indication configuration and interpretation

Regarding the details of how to configure the repetition factor and how to interpret the repetition factor. Two companies provided two proposals.

[**R1-2106498**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106498.zip): Single PUCCH resource can be referred by multiple PUCCH resource sets with different PUCCH repetition factor.

**[R1-2107362](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip):** Support different interpretations of a single dynamic indication of PUCCH repetition factor, for different PUCCH formats and UCI sizes, or different PUCCH resource sets.

Companies are welcome to provide comments to the two proposals in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Samsung | The proposal in R1-2106498 is not necessary and can be achieved/avoided by NW implementation.The proposal in R1-2107362 regarding dependence on PUCCH formats is not necessary as BLER, for a given UCI payload, does not depend on the PUCCH format. Association of repetitions with different PUCCH resource sets is meaningful but can be a NW implementation based on configuration of repetitions per PUCCH resource. Association of repetitions with UCI size is also meaningful and can alleviate PUCCH resource indication restrictions from the WA - we support further consideration.  |
|  |  |
|  |  |

## Other proposals

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 2.1 and 2.2.

[**R1-2106991**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106991.zip): It is not necessary to introduce new candidate values for dynamic PUCCH repetition.

[**R1-2107756**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107756.zip): Specify conditions under which a PUCCH with dynamic indication of repetition number may overlap with another PUCCH repetitions without dynamic indication of repetitions.

[**R1-2107756**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107756.zip)**:** Support the working assumption as an agreement, and combine existing mechanisms based on PRI, NCCE and nCCE,0 to indicate the PUCCH resource with repetition factor within a PUCCH resource set up to 64 resources

* FFS: indication of repetition factor for a FM1 PUCCH provided by *pucch-ResourceCommon*

[**R1-2107562**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107562.zip): Periodic or semi-persistent CSI can use the same basic mechanism as dynamically indicated PUCCH resource

* DCI can update a PUCCH resource used for P/SP-CSI reporting
* P/SP-CSI reporting resources can be selected by DL or UL grants
* PUCCH resources used in periodic and/or semi-persistent CSI reporting can be indicated via DCI in at least a DL grant
	+ FFS: if UL grants can also be used for this purpose
* The dynamic PUCCH repetition mechanism should be applied to all PUCCH formats and all UCI types including A-CSI.

[**R1-2107551**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107551.zip): The following methods to configure PUCCH repetition for the UE without dedicated PUCCH resource configuration should be studied.

* PUCCH repetition is indicated by using repetition number of PUSCH.
* PUCCH repetition is indicated by PRI and/or system information.
* Introduce a PUCCH resource set with repetition number.

[**R1-2107362**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip)**:** Support enhancing RRC signaling to allow dynamic indication of frequency hopping for PUCCH repetition via indication of PUCCH resource.

[**R1-2107362**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip): Also using other properties of PDCCH (e.g. PDCCH aggregation level), in addition to PRI and starting CCE index, to indicate the PUCCH resource.cation of PUCCH resource.

[**R1-2107362**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip)**:** Support implicit indication of PUCCH repetition factor based on beam selection.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Ericsson | Agree that we can come back to these later, since many seem to depend on sections 2.1 and 2.2. |
|  |  |

# 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.

[R1-2106614](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106614.zip): Regarding the use cases for PUCCH DMRS bundling, we have following proposal:

* Use cases 3 and 4a should be supported
* Use cases 4b and 5b should be deprioritized.

[R1-2106742](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106742.zip)*: Decide whether to support Use case 4b/5a/5b for PUCCH repetitions depending on RAN4 further decision.*

[R1-2106905](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip): Support use cases 3,4,5 for DM-RS bundling for PUCCH repetitions.

[R1-2107126](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107126.zip)*: At least support Use case 3 and Use case 4a for PUCCH repetitions with DMRS bundling.*

[R1-2107362](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip) : Support the following use cases:

* 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

Based on the above proposal, it seems at least reasonable to prioritize to study case 3 and 4a in RAN.

**FL Proposal 3: For DMRS bundling for PUCCH repetitions, RAN1 at least prioritize to study use cases 3 and 4a.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| China Telecom | We support this proposal. As for use case 4b/5, it is not clear whether the phase continuity and power consistency across the repetitions can be maintained. Thus, we think use case 3 and 4a should be prioritized.  |
| CMCC | Support. |
| vivo | Support the FL proposal |
| Intel | We are fine with the FL’s proposal |
| Nokia/NSB | We understand possible concerns some companies may have on use case 4b. On the other hand, we think that not supporting it may strongly hinder the likelihood of DMRS bundling for PUCCH to be ever used, due to interactions with PUSCH repetitions framework. We think it is safe to say that if PUCCH suffers coverage shortage, so would PUSCH. Indeed we know from the results obtained during the SI, that PUSCH has more significant coverage issues than PUCCH. Thus, we can expect PUSCH repetitions to be configured very frequently in case of coverage shortage. This is also the reason why RAN1 is specifically focusing on the Type A repetition framework for the enhancements discussed in 8.8.1.1. In this context, scenarios in which repeated PUCCH and PUSCH transmissions form a pattern where a PUSCH repetition occurs between two PUCCH repetitions in non-back-to-back slots seem to be very likely. If we did not support use case 4b, neither PUSCH nor PUCCH repetitions would be able to enjoy from the benefits of JCE. This does not seem the wisest course of action, given how often this could actually happen in practice. |
| Samsung | Use case 5 is a realistic scenario in TDD and should be prioritized. Feasibility is pending RAN4 feedback. We suggest to ask to RAN4 the feasibility of phase continuity and power consistency with a gap larger than 14 symbols (less than 14 symbols confirmed in RAN4 LS reply R4-2105417). Support use cases 3 and 4a.Use case 4b – pending RAN4 feedback. |
| Lenovo, Motorola Mobility | We support the FL proposal |
| Ericsson | While I appreciate the FL’s desire for progress and to simplify the work, RAN4 is still discussing what scenarios/use cases can be supported, and we prefer to minimize our assumptions about what they may conclude. So unless there is a strong need, we think this priority discussion can wait a bit until there is more progress in RAN4. |

## DMRS bundling scheme and signalling

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

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

Agreement: 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 design of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.

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

### Time domain window design details

There are a few key questions RAN1 needs to answer to complete the design of time domain window for DMRS bundling for PUCCH repetition.

Question 1: Allow only one single window or allow one or more windows across all repetitions of a PUCCH?

Question 2: If multiple windows are allowed, allow only a common window duration for all windows or allow different window durations for different windows?

Question 3: How to determine the duration of a window?

Question 4: How to determine the start of a window?

The same set of questions can be raised for PUSCH repetitions. A common design is desired for PUCCH/PUSCH repetitions. Based on views expressed in companies’ contributions, majority companies want to wait for the decision of time domain window design for PUSCH repetition and reuse it for PUCCH. Therefore, in this meeting, before progress made on PUSCH time domain window design, we will focus on signaling aspects of time domain window for PUCCH.

### Signalling to support the time domain window

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

Companies’ views submitted in the contributions are the following:

* Per UE: Nokia, CATT
	+ Rationale: 1) the quality of channel condition is common for all PUCCH formats; 2) This additional flexibility with per PUCCH resource configuration is not justified since we see no disadvantage for a UE to have the DMRS bundling constantly activated each time PUCCH repetitions are scheduled. 3) RRC signalling overhead is high with per PUCCH configuration.
* Per PUCCH resource: QC, DCM, Apple
	+ Rationale: 1) Due to the differences in the number and span of PUCCH repetitions across different PUCCH resources, it is preferred to configure parameters for DMRS bundling for each PUCCH resource separately; 2) with per PUCCH resource configuration, it is allowed to dynamically activate or deactivate the DMRS bundling feature by selecting a specific PUCCH resource through the PRI field in the scheduling DCI.

Since only a few companies provided input to this question in the contributions. FL would like to collect more input before we make a decision on this open issue.

**FL Question 2: the RRC configuration for PUCCH repetition is per UE or per PUCCH resource?**

Companies are welcome to provide answer to the above question in the following table. It is also recommended to provide some justifications for your answer, i.e., why per UE configuration is preferred or vise versa.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| China Telecom | We are a bit confused, is the question here: the RRC configuration for PUCCH repetitions with DMRS bundling is per UE or per PUCCH resource? If so, we think it depends on whether it is the same conditions to satisfy the prerequisite of DMRS bundling for PUSCH and PUCCH. If they are the same, then there is no need to configure per PUCCH resource. Or else, per PUCCH resource configuration can be considered. We are open to discuss it. |
| Intel | Our view is that support of time domain window for PUCCH repetition should be per UE. There is no clear motivation to further consider this per PUCCH resource.  |
| Nokia/NSB | As we discussed in R1-2106658, we see no disadvantage for a UE to have the DMRS bundling constantly activated each time PUCCH repetitions are scheduled. Of course, this must be subject to the respect of the requirements, and to UE capability, if applicable. We are not suggesting mandatory support of DMRS bundling for the UE. This discussion will occur elsewhere at a later time. We are simply suggesting that once all the minimum conditions are met, i.e., the UE supports DMRS bundling and RAN4 requirements are met, then DMRS bundling should just occur whenever PUCCH repetitions are configured. The presence of the time domain window would then guarantee that no ambiguity exists between UE and gNB, as we also discussed for PUSCH in R1-2106657.  |
| Samsung | Above questions have been discussed for the PUSCH for several meetings, and RAN1 agreed to strive for common design PUSCH/PUCCH for joint channel estimation/DMRS bundling. In the interest of time and to have a common design, we suggest to progress the discussion for PUSCH and then discuss PUCCH.This applies also to some discussions in the next sections. |
| Lenovo, Motorola Mobility | We agree with Samsung that same issues have been discussed for PUSCH. And as common design should be considered for PUSCH and PUCCH, therefore, we also agree to discuss this once the agreement is made for PUSCH. |
| Ericsson | We would also prefer to start with per UE configuration of PUCCH repetition. It’s not clear to use yet why the requirements and UE capability would be insufficient to identify PUCCHs that can be bundled. |

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: HW/HiSi, Nokia, Lenovo,
* Needed: Spreadtrum, Samsung, Interdigital

Since only a few companies provided input to this question in the contributions. FL would like to collect more input before we make a decision on this open issue.

**FL Question 3: whether additional dynamic signaling is needed to enable/disable PUCCH repetitions with DMRS bundling? If yes, what are the signaling design details.**

Companies are welcome to provide answer to the above question in the following table.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| China Telecom | We think dynamic signaling is not needed. |
| CMCC | PUCCH repetitions with DMRS bundling should based on RRC configuration. There is no need to enable the function through dynamic signaling. |
| vivo | It has been discussed in PUSCH, and the dynamic signaling discussion is still FFS, we prefer to depend on the discussion for JCE for PUSCH. |
| Intel | RRC signalling is sufficient for enabling/disabling PUCCH repetitions with DMRS bundling. We do not think dynamic signalling is needed.  |
| Nokia/NSB | We confirm our preference. Dynamic signaling is not needed in this case. |
| Samsung | Dynamic signaling can be useful in some channel conditions, such as when it can be beneficial for a UE to apply received TPC commands.In general, it allows a gNB to control whether or not restrictions associated with a TDW for DMRS bundling are beneficial for a given transmission. |
| Lenovo, Motorola Mobility | We do not agree to support dynamic signaling to enable/disable PUCCH repetitions with DMRS bundling |
| Apple | No (Additional dynamic indication is not needed) |
| Ericsson | The performance gains of dynamic signaling vs. its overhead and additional gNB scheduler complexity are not clear to us. RRC seems enough at this stage. |

Regarding the details of dynamic signaling, if needed, there is proposal from [**R1-2107653**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107653.zip).

* Support a grant-type dependent index which indicates to the UE which PUCCH repetitions to bundle

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
|  |  |
|  |  |

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 104e, the following agreements were made under AI 8.8.2.

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 RAN1 104bis-e, the following agreements were made under AI 8.8.1.3. Since RAN1 should trive for common design between PUCCH and PUSCH repetition. The following agreement should be taken into account for the design of PUCCH repetition.

Agreements (RAN1#104-bis-e):

For inter-slot frequency hopping with inter-slot bundling, down select on the following two options:

* Option 1: The bundle size (time domain hopping interval) equals to the time domain window size.
* Option 2: The bundle size (time domain hopping interval) can be different from the time domain window size.
	+ FFS: Whether the bundle size (time domain hopping interval) is explicitly configured or implicitly determined.
	+ FFS: Whether/How the bundle size (time domain hopping interval) is defined separately for FDD and TDD.

FFS: relation between the bundle size (time domain hopping interval) and the time domain window size

There are three key questions RAN1 need to answer to complete the design for this topic.

Question 1: how to determine the bundle size (time domain hopping interval) for PUCCH/PUSCH

Question 2: whether the bundle size (time domain hopping interval) equals to the size of time domain window

Question 3: What is the interaction between the determination of time domain hopping interval determination and the determination of time domain window for DMRS bundling? In other words, when the two features, DMRS bundling and frequency hopping, are enabled simultaneously, a UE should determine the hopping intervals first or determine the window(s) for DMRS bundling first?

The first two questions are related to the design of hopping interval. Again, it is desired to have a unified design between PUCCH and PUSCH. Therefore, we will wait for progress in 8.8.1.3 and reuse the design in 8.8.1.2 for 8.8.2.

The third question is on the interaction between the two features of DMRS bundling and frequency hopping. FL would like to start some discussion on this topic. Apparently, there are at least two options as below.

* Option 1: A UE determines the time window(s) for DMRS bundling first. After the time window(s) for DMRS bundling is determined, the UE determines the hopping interval(s) and corresponding hop position for each hopping interval.
* Option 2: A UE determines the hopping intervals first. After the hoping intervals are determined, the UE determines the time window(s) for DMRS bundling.

There maybe other options/solutions that FL missed. Companies are welcome to provide input on this topic.

**FL Question 4: What is the interaction between the determination of time domain hopping interval determination and the determination of time domain window for DMRS bundling? In other words, when the two features, DMRS bundling and frequency hopping, are enabled simultaneously, a UE should determine the hopping intervals first or determine the window(s) for DMRS bundling first?**

Companies are welcome to provide answer to the above question in the following table.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| China Telecom | We think the situation for paired and unpaired spectrum is different, and can be discussed separately. For paired spectrum, the TDM for bundling can be determined first then, the hopping interval is equal to the TDM. For unpaired spectrum, the hopping interval is related to DL/UL configuration. |
| CMCC | As the bundling size/ time domain window has a strong impact to the hopping pattern, the window of bundling should be determined first. |
| Vivo | Similar issue has been discussed in PUSCH repetitions with frequency hopping, we prefer a common design for both PUCCH and PUSCH. |
| Intel | We think there is some connection between time domain window size and frequency hopping bundle size. In our view, when inter-slot frequency hopping with inter-slot bundling is applied, the time domain window size can be determined by the bundle size. |
| Nokia/NSB | We think that it is not possible to provide and answer to Question 3 before agreeing on an answer to Question 2. We first need to agree on whether the time hopping interval can be different from the time-domain window duration. If the two durations coincide, then discussing on which one is determined first does not seem relevant. The converse is true if we agree that the two durations are, or can be, different. Indeed, as of today, there is no answer to the following question: is the hopping occurring within the time domain window or between two time-domain windows (e.g., inter-window hopping). In turn, this question cannot be answered unless the following is answered first: is there only one or multiple time-domain windows?  |
| Samsung | For paired spectrum, the time domain hopping interval is same as the TDW for DMRS bundling. There is no reason for differentiation and a smaller TDW will result to worse coverage. The same can apply for unpaired spectrum subject to conditions for maintaining phase continuity. In general, the TDW should be equal to the number of repetitions for which conditions for the UE to maintain phase continuity are satisfied. There is no need for additional rules and they will only result to worse coverage.  |
| Lenovo, Motorola Mobility | In our view, the time domain window size and the bundle size for inter-slot frequency hopping should be related and only one of them need to be configured/indicated. |
| Ericsson | We think the UEs should determine the frequency hopping intervals first. One reason is that not all UEs in a cell may be configured for, or even support, DMRS bundling. In order to have spectrally efficient use of PUCCH, UEs not configured for bundling but that share the same PRBs should be able to hop with UEs using DMRS bundling and hopping.  |

## Other proposals

[R1-2107562](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107562.zip) proposed the following to study the technique of relative phase correction at gNB. This proposal has been discussed in RAN1 #105e without conclusion. We can continue the discussion in this meeting.

* 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.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Samsung | We do not support proposals requiring/assuming specific gNB implementations that may not be considered typical. |
| Ericsson | Given the increasingly clear limitations on when UEs can maintain phase continuity, we would hope companies will consider this proposal. |
|  |  |

Regarding the issue of PUCCH with repetition/DMRS bundling overlap with other PUCCH without repetition/DMRS bundling, [R1-2107756](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107756.zip) proposed the following proposals.

* Specify conditions under which a PUCCH with dynamic indication of repetition number may overlap with another PUCCH repetitions without dynamic indication of repetitions.
* 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.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Samsung | For the first bullet, Rel-16 conditions remain applicable. This does not seem related to coverage enhancements.For the second bullet, we’re fine to further discuss but it is unclear what is different relative to the case where a UE does not transmit a repetition when there is collision with DL symbols.  |
| Apple | Given that dynamic indication of repetition bring another level of indication (in comparison with R15/16 where PUCCH repetition is RRC indicated), it is expected such a PUCCH receives more protection against dropping rules, if possible (e.g. if dropping condition could be set dynamically as well). Having said that, we would like to further discuss this problem.  |
|  |  |

# Power control and TA with PUCCH repetitions

[**R1-2106905**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip)mentioned the power control issue with PUCCH repetition. Given that UE can not adjust Tx power during the time window (for DMRS bundling), how to handle a received TPC with action time falls into the time window? On high level, two options can be considered. Option 1 is discarding this TPC. Option 2 is deferring the action time of this TPC to the time window boundary. Besides the options, [**R1-2107756**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107756.zip)also proposed another solution “Proposal 6: 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” and “Proposal 7: Unicast DCI with a TPC command implicitly indicates that DMRS bundling is off, from the occasion that new TPC is applied”.

A similar issue needs to be considered on how to handle a received TA command with action time falls into a time window (for DMRS bundling)

**FL Question 5: What is the UE behavior for a received TA command or power control command whose appliance time falls into a time window for DMRS bundling for PUCCH/PUSCH repetition.**

Companies are welcome to provide answers to the above question in the following table.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| China Telecom | Based on RAN4’s LS, both TA and transmit power adjustment will break the phase continuity or power continuity. Thus, if TA command or TPC is received by UE during the configured time domain window, we think a simple way is that the UE not perform TA or transmit power adjustment. |
| CMCC | Our initial thinking is that for the TA command, it could be ignored. And for the power control, the TPC command could be accumulated but not take into practice. When the time domain window is closed, UEs could transmit in the updated power. |
| Intel | Our view is that as gNB is aware of UEs that perform DMRS bundling for PUSCH repetition, gNB can simply disable TPC command (DCI format 2\_2) or TA adjustment command during the time domain window for the corresponding UEs. |
| Nokia/NSB | We think that this depends on how many time-domain windows are defined for the DMRS bundling / JCE. The two cases, i.e., one or multiple time-domain windows, may need different rules to be specified in case TA command of TCP is received by UE during a time-domain window. Problem could be solved rather easily if multiple windows were used. |
| Samsung | RAN4 reply LS (R1-2106423) addressed those questions.  |
| Apple | Yes, RAN4 reply LS confirms phase continuity will be lost “if” UE is supposed to apply the TA. Obviously from the comments above, we need to discuss UE behavior (e.g. that is an indication to UE to stop DMRS bundling, or UE ignores TA, etc)  |
| Ericsson | These issues should probably first be resolved for PUSCH. However, we think that the UE should not apply TA updates between transmissions belonging to the same DMRS bundle, although it is FFS for us if there might be exceptions if the TA update is large. For power control commands, if for some reason a power control command changes the power of one PUCCH repetition relative to another, would it be sufficient for the gNB to assume that consistency/continuity is not maintained? Moreover, it would be helpful to understand the scenarios people have in mind where PUCCH power would vary across repetitions. |

# References

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| --- | --- | --- |
| [**R1-2106498**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106498.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [**R1-2106614**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106614.zip) | Discussion on PUCCH enhancements | vivo |
| [**R1-2106658**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106658.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [**R1-2106712**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106712.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [**R1-2106742**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106742.zip) | Discussion on coverage enhancements for PUCCH | ZTE |
| [**R1-2106905**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106905.zip) | PUCCH enhancements | Samsung |
| [**R1-2106991**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106991.zip) | Discussion on PUCCH enhancement | CATT |
| [**R1-2107118**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107118.zip) | Discussion on PUCCH enhancement for NR coverage enhancement | Panasonic Corporation |
| [**R1-2107126**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107126.zip) | Discussion on PUCCH enhancements | China Telecom |
| [**R1-2107142**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107142.zip) | Discussion on PUCCH enhancements | NEC |
| [**R1-2107193**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107193.zip) | Enhancements for PUCCH repetition | Lenovo, Motorola Mobility |
| [**R1-2107259**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107259.zip) | PUCCH enhancements for coverage | OPPO |
| [**R1-2107362**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107362.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [**R1-2107420**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107420.zip) | Discussion on PUCCH enhancements | CMCC |
| [**R1-2107477**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107477.zip) | PUCCH enhancements | ETRI |
| [**R1-2107551**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107551.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [**R1-2107562**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107562.zip) | PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [**R1-2107605**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107605.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [**R1-2107653**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107653.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [**R1-2107756**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107756.zip) | PUCCH coverage enhancement | Apple |
| [**R1-2107802**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107802.zip) | PUCCH coverage enhancement | Sharp |
| [**R1-2107875**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107875.zip) | PUCCH enhancements | NTT DOCOMO, INC. |
| [**R1-2107938**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107938.zip) | Discussion on PUCCH enhancements | Xiaomi |