**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.** |
| LG | Since the P/SP CSI does not have a corresponding DCI, in order to dynamically indicate it, introducing a new DCI for indication for this purpose or an implicit indication method can be considered. Introducing corresponding DCI is not feasible since it leads too large spec impact. On the other hand, indicating in an implicit way has too large a spec impact either, and the simplest way to dynamically indicate it is using AP CSI, which is feasible. Therefore, it is not supported. |
| Sharp | We don’t support dynamic PUCCH repetition factor indication to P/SP-CSI.  For example, both semi-static PUCCH with 8 repetitions and dynamic PUCCH without repetition can be realized to maximize coverage for the semi-static PUCCH without disturbing utilization efficiency of the dynamic PUCCH.  We support dynamic PUCCH repetition factor indication to HARQ-ACK for SPS PDSCH if the same PUCCH repetition factor indication mechanism can be reused. |
| Panasonic | We think periodic is purely semi-static configuration, and therefore, to support dynamic indication is difficult. The repetition factor for periodic CSI would be set considering the maximum payload size of CSI reporting. For semi-static CSI or HARQ-ACK for SPS PDSCH, to introduce PRI like indication to activation DCI is one of possibility if the motivation to introduce dynamic indication is clarified. |
| NEC | We don’t support dynamic PUCCH for P/SP-CSI. It may increase indication complexity and the gain seems to be not large compared with legacy static PUCCH repetition.  We think dynamic PUCCH repetition factor for SPS PDSCH can be supported without any extra effort. |
| CATT | Do not support dynamic PUCCH repetition factor indication to HARQ-ACK for SPS PDSCH. The flexibility is still limited even if the PUCCH repetition number for SPS-PDSCH could be dynamically indicated by the active DCI, since the repetition number remains unchanged until a new active DCI is received. |
| ZTE | We don’t support dynamic PUCCH repetition for P/SP-CSI and SR. There is no associated PRI for dynamic indication.  Support dynamic PUCCH repetition factor for SPS PDSCH HARQ-ACK, otherwise additional spec effort is needed. Because PRI in activation DCI would anyway indicate a PUCCH resource for SPS PDSCH HARQ-ACK, and the indicated PUCCH resource could be associated with one repetition factor. Without any additional clarification, dynamic repetition would be automatically supported for SPS PDSCH HARQ-ACK. |
| Spreadtrum | Dynamic signalling is not needed. Instead, we may study implicit ways to enable PUCCH repetition factor indication to P/SP CSI /SR/HARQ-ACK/SPS PDSCH. |
| Xiaomi | Do not support dynamic PUCCH repetition factor indication for P/SP-CSI or HARQ-ACK for SPS PDSCH. |

## 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. |
| LG | Not a critical issue.  It might be concern if only PRI and repetition number has 1:1 mapping relationship, however in our view, it is one alternative for dynamic indication among many options. |
| Sharp | No, some of the 4 numbers of repetitions can be configured on one PUCCH resource set and PUCCH resources with the same PUCCH resource index in the different PUCCH resource sets can have different repetition numbers. |
| Panasonic | The WI can be confirmed. We agree to the concern on less flexibility issue when keeping the number of PRI bits. We think to extend the number of PRI bits is reasonable solution if the flexibility is a critical issue. |
| NTT DOCOMO | We support to confirm the working assumption. |
| NEC | Confirm WA. Although limited 3 bits PRI have some impact on network scheduling, it’s not a big issue, network can handle it. |
| CATT | Not critical. There is no need for each resource to always be associated with all of the 4 repetition numbers. Since the top priority in PUCCH enhancement is to guarantee the coverage of PUCCH, small sacrifice of the flexibility can be acceptable. |
| ZTE | The issue is not critical. Support to confirm the WA. |
| Spreadtrum | Not critical. We think it is an implementation issue and can be solved properly via NW. Confirm WA. |
| Xiaomi | Confirm the WA. |
| Huawei, HiSilicon | Thank Samsung for raising the issue of capacity. In our understanding, only some PUCCH resources are needed to be configured with repetition number. It is not critical to allow 4 repetition numbers configured for each PUCCH resource. Therefore, we prefer to confirm the WA. |

Based on the input in the above table, all companies are fine to confirm the working assumption. Therefore, the following FL proposal is made.

**FL Proposal 0: Confirm the following working assumption.**

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

Companies can express your concern if you object the above FL proposal.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| LG | Support to confirm the working assumption. |
|  |  |
|  |  |

### 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. |
| LG | Sub-slot-based PUCCH repetition is corresponding to use case 1, and it was not agreed to support this use case in PUCCH. Therefore, a discussion on this should be preceded.  In addition, even if we agree to support use case 1, about the application format of dynamic indication, format 1, 3, 4 based on the dynamic indication method and considering the method of applying it to sub-slot repetition according to the agreement is under discussion at URLLC, so it is better to deal with the WI.  The FL's summary has not yet been released in the related agenda, but considering the contributions and the summary of the last meeting (R1-2106249), it seems that it is being discussed in relation to it. |
| Panasonic | We are fine with the proposal. |
| NTT DOCOMO | We support the proposal. |
| NEC | Fine with the proposal. |
| CATT | We originally did not support short PUCCH formats 0 and 2. But now we reconsider our position, since there may be some benefit even in URLLC case. OK with this proposal in principle. |
| ZTE | Fine with the proposal, as it seems no additional efforts are needed for support of short PUCCH formats. |
| Spreadtrum | Support |
| Xiaomi | Fine with the proposal |
| Huawei, HiSilicon | In our understanding, the proposal is not needed for the following reasons,   * The second FFS in the first cited agreement says that the URLLC group will discuss whether and how to reuse the mechanism developed in this CovEnh WI for URLLC. No need to have overlapping discussion in CovEnh WI. * The focus of this WI is coverage enhancement, the proposed enhancement for PUCCH format 0 and 2 are not motivated for coverage enhancement. If it has been agreed to support in URLLC WI, its spec impact development will be completed in the same URLLC WI. It is not clear why its support has to be re-discussed in this WI. |
| Apple | We are not against what is already agreed in this AI or any other AI. To us, what FL says, “*dynamic PUCCH repetition factor indication for short PUCCH formats is already supported*” is not 100% correct (as if it was, there was no point to agree with something that is already agreed!). As the agreement in URLLC says, slot-based PUCCH repetition with short PUCCH formats, which it the matter of this agenda item, is NOT agreed yet (it is FFS). So no, we cannot support this proposal. BTW, we first need to agree on repetition for a PUCCH format and next discuss whether or not to support dynamic indication of repetition factor… The former is still missing ☺ |

### 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 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, is equal to the new repetition parameter;
    - elseif nrofSlots is configured on the PUCCH format, is equal to nrofSlots;
    - otherwise, .

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 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, is equal to the new repetition parameter;**
    - **elseif nrofSlots is configured on the PUCCH format, is equal to nrofSlots;**
    - **otherwise, .**

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 |
| LG | It is necessary to discuss whether the dynamically indicated repetition number will be used only once, or whether it will be used continuously after the indication. For example, consider the options for whether to override the number of repetitions indicated by the PUCCH resource in nrofSlots, or to maintain for a certain time. |
| Sharp | Support |
| Panasonic | We are fine with the proposal. |
| NTT DOCOMO | We support the proposal. |
| NEC | Support. |
| CATT | Support the proposal. |
| ZTE | Support |
| Spreadtrum | Support |
| Xiaomi | Support |
| Huawei, HiSilicon | Samsung’s suggestion seems better. |

Based on the comments collected in the above table, the following update FL proposal is made.

**Updated FL Proposal 2: for a PUCCH resource, if both a new repetition parameter corresponding to Rel-17 dynamic PUCCH repetition factor indication and the Rel-15/16 nrofSlots are configured, the new repetition parameter overrides nrofSlots.**

* **FFS: Whether the overriding is only effective when the PUCCH resource is indicated by DCI or it is effective regardless the PUCCH resource is indicated by DCI/RRC.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | We are fine with the updated FL proposal 2. |
| CATT | Support in principle. Regarding to the FFS part, we think the overriding is only effective when the PUCCH resource is indicated by DCI. |
| LG | Fine with the proposal. |

### 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. |
| LG | We cannot support to increase repetition number without strong concern. Also the expansion of PUCCH repetition number is not described in objective of WID, we think it is out of scope. |
| Sharp | In R1-2107802, we proposed 1, 2, 4, 8 repetitions for the slot-based PUCCH repetition. |
| NTT DOCOMO | We think that increasing repetition is not in the scope. |
| NEC | We think up to 8 is enough. Longer repetition factor may need more DL HARQ processing. |
| CATT | There seems to be a typo in the second bullet {1, 2, 4, 8}.  Increasing the repetition number to enhance the coverage for PUCCH is out of scope. The existing numbers should be enough. |
| ZTE | Share with CMCC. |
| Spreadtrum | We think values larger than 8 are not needed. |
| Xiaomi | Increasing the repetition number is another question that is out of scope. |
| Huawei, HiSilicon | Not support. Out of scope. |

Based on the collected feedback in the above table. FL propose the following conclusion.

**Proposed conclusion 1: In Rel-17, PUCCH repetition factor larger than 8 is not supported.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | We agree the proposed conclusion 1. |
| CATT | OK. Though it may be better to directly confirm that the current set {1, 2, 4, 8} is reused. |
| LG | Fine in principle, however since enhancement in number of repetition is out of scope, it would be better to be described as:  “Rel-16 PUCCH repetition number is reused for dynamic PUCCH repetition factor indication.” |

### 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. |
| CATT | Neither of them has clear benefit to us. |
| Huawei, HiSilicon | Regarding the proposal in R1-2106498, thank you for your comments.  @Samsung, according to the current RRC configurations for PUCCH resource and resource set, a PUCCH resource can be referred/shared by different PUCCH resource sets, as cited below. We would like to keep such flexibility instead of forcing NW to configure different PUCCH resource IDs to different repetition numbers even though all the remaining parameters of the PUCCH resource are the same. Please note that the maximum number of PUCCH resource IDs is limited to 128 in current spec. |

## 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. |
| LG | We are currently discussing the dynamic indication method of PUCCH repetition according to the objective of WID. In the case of PUCCH repetition, the instruction method is different depending on the case of with dedicated PUCCH resource and without dedicated PUCCH resource, and a discussion is required for each. The without dedicated PUCCH resource means a PUCCH case for sending A/N for msg4 PDSCH.  The direction of the current discussion is one of the methods of mapping the number of repetitions to the PUCCH resource, which is difficult to directly apply to PUCCH without a dedicated PUCCH resource. Therefore, it is necessary to discuss the application method of the dynamic indication for without dedicated PUCCH resource, and as a method, it is appropriate to introduce a resource set with a repetition number. |

# 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. |
| LG | Support FL’s proposal. |
| Sharp | Support |
| Panasonic | We are fine with the proposal. |
| NTT DOCOMO | We support the proposal. |
| Qualcomm | Support. |
| CATT | Support the proposal. |
| ZTE | Support |
| Xiaomi | Support |

## 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 DMRS bundling across PUCCH repetitions 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. |
| Sharp | We prefer “per UE” but we should not conclude this because RRC configuration for PUCCH repetition with DMRS bundling is unclear. |
| Panasonic | We have same clarification question as mentioned by China Telecom. The question here would be the RRC configuration for PUCCH repetitions with DMRS bundling is per UE or per PUCCH resource. We think DMRS bundling is enabled is per UE configuration. However, depending on slot pattern, hopping and/or the repetition, there can be the situation of no DMRS bundling. |
| Qualcomm | As mentioned before, it may not be prudent to enable DMRS bundling for all PUCCH resources. DMRS bundling does not come for free at a UE and its best to use it in a selective manner for a small subset of PUCCH resources. Further as stated earlier, number of repetitions, TDRA, and frequency hopping configurations are likely to be different across PUCCH resources and it may not make sense to enabling bundling across the board using a single set of parameters. For these reasons, we prefer that DMRS bundling be configured per PUCCH resource. |
| CATT | Per UE is preferred. The quality of channel condition is common for all PUCCH formats. If a UE is in the scene of deep fading, the performance of the PUCCH transmission would always be terrible no matter which PUCCH format is used. |
| ZTE | Per UE configuration for PUCCH repetition is preferred. If DMRS bundling of PUSCH repetition doesn’t require different RRC configurations depending on different scheduling, we don’t see the motivation for configuration per PUCCH resource.  Further discussion is needed about whether to use a same RRC configuration with PUSCH repetition or TBoMS. |
| Spreadtrum | We prefer “per UE”. Share same view as Samsung/Lenovo, could wait for the progress of PUSCH. |
| Xiaomi | Per UE configuration is preferred. No obvious benefit for configuration per PUCCH resource. |
| Huawei, HiSilicon | Since the condition to maintain phase contiguity for DMRS bundling are the same for different PUCCH resources, we prefer “per UE”. OK to Samsung and Lenovo’s suggestions, make progress on PUSCH first. |

Based on feedback collected in the above table, the views from different companies are summarized as below.

Support per UE configuration: Intel, Nokia, CATT, Ericsson, Sharp, Panasonic, ZTE, Spreadtrum, Xiaomi, HW/HiSi

Support per PUCCH resource configuration: QC

FL’s assessment is that this is not a very critical issue. It is basically flexibility vs RRC overhead. Since majority does not see the need to go with per PUCCH resource configuration, FL recommend to take the majority view and conclude this issue.

**FL Proposal 4: The DMRS bundling with PUCCH repetitions is configured per UE by RRC.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | As we commented in the first round, the DMRS bundling configuration is currently unclear. Therefore, we should wait for more agreement regarding the configuration for PUSCH. |
| CATT | Support. Also fine to wait for more progress in PUSCH JCE, to achieve a unified design. |
| LG | As other companies mentioned, for common design of DMRS bundling of PUSCH and PUCCH, it should be discussed after DMRS bundling of PUSCH is settled. |

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 ignallin is sufficient for enabling/disabling PUCCH repetitions with DMRS bundling. We do not think dynamic ignallin is needed. |
| Nokia/NSB | We confirm our preference. Dynamic signaling is not needed in this case. |
| Samsung | Dynamic ignalling 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. |
| LG | Not support. Same discussion is ongoing in joint channel estimation of PUSCH agenda. Duplicating discussion should be avoided. |
| Sharp | We think it is not needed because mis-understanding between gNB and UE occurs when the UE failed to detect the dynamic signaling. |
| Panasonic | Depending on the event, the power consistency and phase continuity are violated. The DCI assignment may result not to satisfy the power consistency and phase continuity condition. In such case, it results disable joint channel estimation. We don’t see the need of “explicit” disable joint channel estimation by DCI. |
| NTT DOCOMO | We prefer to have a unified design with PUSCH. |
| CATT | We think additional dynamic signaling is not needed. Similar to DOCOMO, we prefer to have a unified design with PUSCH, where the dynamic signaling is not agreed yet. |
| ZTE | No dynamic signaling is needed. |
| Spreadtrum | Not support. Semi-static signaling is sufficient. |
| Xiaomi | We prefer a unified design with PUSCH and there is no need to have a dynamic signaling. |
| Huawei, HiSilicon | Since only one PUCCH payload is assigned in PUCCH repetition, we don’t see any benefit of the proposed dynamic signaling. Additionally, we prefer to make progress on PUSCH first. |

Based on the input collected in the above table, companies’ views are the following:

* Additional dynamic signaling is not needed: CT, CMCC, Intel, Nokia, Lenovo, Apple, Ericsson, LG, Sharp, Panasonic, CATT, ZTE, Spreadtrum, Xiaomi, HW/HiSi
* Additional dynamic signaling is needed: Samsung

FL’s assessment is that, this is again a tradeoff between flexibility and signaling overhead, which is not a very critical design issue. Since majority companies do not see the need to introduce dynamic signaling for this feature, FL make the following conclusion.

**Proposed conclusion 2: Dynamic signaling to enable/disable DMRS bundling with PUCCH repetitions is not supported in Rel-17.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | We agree the proposed conclusion 2. |
| CATT | Support. Also fine to wait for more progress in PUSCH JCE, to achieve a unified design. |
| LG | Support. |

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** |
| LG | We still do not see the clear reason why we need dynamic signaling for DMRS bundle. It should be clarified first. |
|  |  |

## 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. |
| LG | Since the same discussion is ongoing in joint channel estimation, it is better not to discuss it here in order to avoid duplication, and it is appropriate that it is commonly applied to PUSCH and PUCCH. |
| Sharp | In our view, a UE should determine the hopping intervals first. This is because the hopping pattern should be configured/indicated independently from DMRS bundling to multiplex among UEs. |
| Panasonic | A length of time domain window and a length of inter-slot FH are the same or not depending on the pattern of inter-slot FH. |
| NTT DOCOMO | We prefer to have a unified design with PUSCH. |
| Qualcomm | Same views as Ericsson/Sharp. |
| CATT | We also prefer a common design for both PUCCH and PUSCH. Our preliminary consideration is that, the hopping point should be considered when determining the time domain window, since the frequency hopping would damage phase continuity. The PUCCHs in the hopping intervals are the actual transmissions for DMRS bundling. Hence, a UE should determine the hopping intervals first. |
| ZTE | It depends on how to design the time domain window. In addition, we also prefer a unified design with PUSCH. |
| Spreadtrum | We think the length of time window highly depends on the hopping interval, meaning hopping interval should be determined first. |
| Xiaomi | Same view with CATT. |
| Huawei, HiSilicon | The RAN1 mechanism should be band agnostic. Additionally, a common design for both PUCCH and PUSCH is needed. |

## 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. |
| LG | It seems gNB implementation to us. |
| Qualcomm | Are all gNBs likely to support this implementation? If not, does a UE have to interface with two types of gNBs requiring two different sets of phase continuity requirements? |
| CATT | From reception point of view, the proposal seems forcing the gNB to have some specific implementations, which is not desired to us. |
| ZTE | Our understanding is current requirements defined in RAN4 have not considered phase correction from gNB side. Therefore, we wonder how could we know whether/how many corrections gNB could do without any RAN4 input. |

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. |
| LG | It seems priority rule of DMRS bundle and since the same discussion is ongoing in joint channel estimation, it is better not to discuss it here in order to avoid duplication, and it is appropriate that it is commonly applied to PUSCH and PUCCH. |
| Sharp | We think overlapping rule in Rel-16 need not be changed. |
| Qualcomm | Legacy rules on prioritization can be applied. No further consideration is necessary. |
| CATT | Rel-15/Rel-16 rules should be sufficient. |

# 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. |
| Qualcomm | UE does not apply TPC/TA commands during a TDW. We can discuss separately whether the intervening commands are accumulated or discarded. |
| CATT | For power control, similar discussion is also on-going in PUSCH with three alternatives. The same mechanism can be reused in PUCCH.  For the TA command, since it would cause phase to change according to RAN4’s reply, UE may ignore the command or not perform the command after the end of the time domain window. |
| ZTE | We can discuss this under the email discussion for RAN4 reply LS. |
| Xiaomi | Discuss it later or follow the same mechanism with PUSCH. |
| Huawei, HiSilicon | It can be come back after progress is made on PUSCH for this issue. |
| LG | It is clear that TA and TPC command should not be applied during the DMRS bundle, however as other companies stated, same mechanism should be applied for PUSCH. Therefore we can discuss it in 8.8.1.3.  @Samsung, @ ZTE  From our understanding, the UE behavior should be described not to perform TA adjustment during DMRS bundle since it is concluded that TA adjustment cause phase to change from the reply LS from RAN4. Regarding it, NWM instead of email discussion is ongoing and only scenarios about downlink reception is provided. It should be discussed in 8.8.1.3. |

# 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 |