**3GPP TSG RAN WG1 #106bis-e R1-211xxxx**

**e-Meeting, October 11th – 19th, 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, the following agreement is made in RAN1 106e.

**Agreement**

**Dynamic PUCCH repetition factor indication for SR or P/SP-CSI on PUCCH is not supported in Rel-17.**

With the above agreement, in R1-2109889, a potential ambiguity is observed. The ambiguity is that whether SR or P/SP-CSI on PUCCH can utilize a PUCCH resource configured with repetition factor “nrofSlots-r17”. The following proposal is made, which basically allow UE to use the PUCCH resource configured with repetition factor “nrofSlots-r17”. But UE ignore the RRC parameter “nrofSlots-r17” and use the legacy RRC parameter nrofSlots to determine the repetition factor for this particular PUCCH resource.

In R1-2109889, Proposal 1: in the case a PUCCH resource is not associated with a scheduling DCI (e.g. PUCCH resource associated with CSI report) and the PUCCH resource is characterized by a dynamic repetition factor, the parameter nrofSlots is used for determining the repetition factor of the specific PUCCH resource.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Current agreement defines a principle: dynamic PUCCH repetition factor indication does not apply to SR or P/SP-CSI. However, this principle can be realized in at least two ways in practice:   1. SR and P/SP-CSI can only be mapped to PUCCH resources for which a number of repetitions is not configured, i.e., the per format config is used. 2. SR and P/SP-CSI can be mapped to any PUCCH resource, regardless of whether a per-resource number of repetitions is configured. When no per-resource rep. factor is configured then per format config is used. Conversely, when per-resource rep. factor is considered, then per format config is used instead.   Proposal 1 in R1-2109889 proposes to go for the understanding described in Approach 2.  As a matter of fact, both ways have pros and cons. However, Approach 2 seems the best approach for the following reasons.  According to Approach 1, NW would always need to configure at least a few PUCCH resources with no per-resource rep. factor configured, to accommodate for SR and P/SP-CSI. This creates a needless redundancy of configurations, which in turn would cause a reduction of the possible resource allocation options at NW when scheduling that resources of several UEs, which need to be properly fit in the time-frequency grid of the uplink or flexible slots (in this sense, the larger flexibility NW’s scheduler has, the better it is).  Conversely Approach 2 offers the possibility, if needed, to have a per-resource rep. factor configuration for each configured PUCCH resource. Thus, all PUCCH resources could have a per-resource configured rep-factor, but whenever such resources are used for SR of P/SP-CSI, the per format rep. factor applies instead (to ensure the most suitable SNR-depending rep. factor can be used). This would maximize flexibility of NW’s scheduler, both for the single and for the multi-UE case, since no “choice” would need to be made on “which PUCCH resource should be configured for SR and P/SP-CSI”. In fact, all PUCCH resources could be used for any PUCCH transmission now, and only UE’s behavior would be different (depending on what is actually transmitted on the PUCCH) but not more complex. |
| Intel | It seems the proposal is fine.  For PUCCH resource which is not associated with a scheduling DCI, if gNB configures the PUCCH resource with repetition factor, repetition factor configured within the PUCCH resource would override the repetition factor which is configured for the PUCCH format. |
| Apple | Without this proposal, gNB shall not map PUCCH without associated DCI to per resource repetition factor (which is our view). To save signaling overhead, we are ok to assume “otherwise” is ignored by UE, i.e. if (for example) SR is mapped to a PUCCH with dynamic repetition factor, UE just ignores the parameter and takes per format repetition factor, if configured. |

For the scope of dynamic PUCCH repetition factor indication, the remaining open issue is whether to support dynamic PUCCH repetition factor indication to HARQ-ACK for SPS PDSCH?

Regarding the above open issue, companies have the following proposals.

In R1-2108848: Proposal 1: Dynamic PUCCH repetition indication is supported for HARQ-ACK for the first SPS PDSCH with associated with the activation DCI, while not supported for HARQ-ACK for the remainging SPS PDSCHs other than the first SPS PDSCH

In R1-2109243: Proposal 2: It is not necessary to apply dynamic repetition factor indication on the HARQ-ACK feedback for SPS PDSCH.

In R1-2109457: Proposal 4: Dynamic PUCCH repetition factor indication for HARQ-ACK for SPS PDSCH can be considered. If supported, dynamic PUCCH repetition factor indication should be based on PRI in activation DCI.

In R1-2109627: Proposal 1: Dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH is not supported.

In R1-2110215: Proposal 1: Defer consideration of support for dynamically indicated PUCCH repetition factor for HARQ-ACK of SPS PDSCH to when it can be addressed together with dynamically indicated PUCCH repetition factor for periodic and semi-persistent CSI

In R1-2110204 Proposal 2: Support applying dynamically indicated PUCCH repetition factor to PUCCH carrying Ack/Nack for SPS

* FFS details, e.g. it can be implicitly indicated based on configuration of PUCCH resource for each PUCCH, or by switching of associated PUCCH resources, implicitly based on the dynamic indication via PDCCH
* FFS the required configuration changes
* FFS the expiry of the repetition factor for other PUCCH (or whether it should be applied in a semi-persistent manner).

The following are the input collected during RAN1 106e in email discussion, which is provided here for information purpose.

|  |  |
| --- | --- |
| **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. |

Given this issue has been discussed for a few meetings, it would be good to conclude this issue as soon as possible. But before settling down this issue, FL would like to collect companies’ view on the following aspects related to SPS PDSCH.

**FL question 1: Whether the** **HARQ-ACK for the first SPS PDSCH associated with the activation DCI is considered as SPS HARQ-ACK or dynamic HARQ-ACK? In other words, whether dynamic PUCCH repetition indication is supported for HARQ-ACK for the first SPS PDSCH associated with the activation DCI?**

**FL question 2: Whether the HARQ-ACK corresponding to the** **SPS Release DCI is considered as SPS HARQ-ACK or dynamic HARQ-ACK? In other words, whether dynamic PUCCH repetition indication is supported for HARQ-ACK corresponding to the SPS Release DCI?**

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

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Nokia/NSB | In our view, current specification should be kept. The HARQ-ACK corresponding to the SPS PDSCH associated with the activation DCI is considered dynamic HARQ-ACK. The HARQ-ACK corresponding to the SPS Release DCI is considered dynamic HARQ-ACK. Possible, arguably unnecessary, optimizations made available by this situation should be up to NW and no further optimization to HARQ-ACK for SPS PDSCH should be performed in this AI. |
| Intel | Our understanding is that HARQ-ACK for the first SPS PDSCH associated with the activation DCI and HARQ-ACK corresponding to the SPS Release DCI are considered as dynamic HARQ-ACK feedback, given that it is determined based on PRI and/or CCE index.  We think it may not be necessary to consider dynamic repetition factor indication for these HARQ-ACK, also including HARQ-ACK for SPS PDSCH. |
| Samsung | If a PUCCH transmission with HARQ-ACK is associated with a DCI format that indicates a PUCCH resource, it does not matter if the HARQ-ACK in response to TB reception, SPS PDSCH activation/deactivation, SCell dormancy, or possible other cases introduced in Rel-17. If the PUCCH transmission with HARQ-ACK is not associated with a DCI format that indicates a PUCCH resource, such as a PUCCH with HARQ-ACK only for SPS PDSCH receptions, Rel-16 applies. Basically, current agreements and specifications are sufficient to describe the UE behaviour. |
| Apple | HARQ-ACK for activation/release SPS “are” associated with DCI, and by default are excluded from this discussion, in our view. Now to extend dynamic indication of repetition factor to other than the 1st SPS PDSCH, for which in current spec the PUCCH resource is RRC indicated, is not needed. |

## Applicability of dynamic PUCCH repetition factor indication

Based on the agreements/conclusion made in RAN1 #105e and RAN1 #106e 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

**Conclusion**

The dynamic repetition indication solution for slot-based PUCCH repetition from the RAN1#105-e working assumption from Cov. Enh. WI can be directly applied for dynamic repetition indication for sub-slot based PUCCH repetition.

**Agreement**

Support slot-based PUCCH repetition for PUCCH Format 0 and Format 2 also for single TRP operation.

The support is subject to independent UE capability indication

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 conclusion to clarify the applicability of dynamic PUCCH repetition.

**FL proposed conclusion 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 conclusion in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Agree. |
| InterDigital | Support. |
| Intel | We are fine with the conclusion. |
| Samsung | OK |
| Lenovo, Motorola Mobility | Support the FL’s proposed conclusion |

## 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.

In R1-2110049, Proposal 6: Support the existing mechanism in 38.213 Sec. 9.2.3 when number of resources per PUCCH resource set is up to 32.

* 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 PUCCH resources

In R1-2110204, Proposal 1: Also using other properties of PDCCH (e.g. PDCCH aggregation level), in addition to PRI and starting CCE index, to indicate the PUCCH resource.

In R1-2110204, Proposal 3: Support enhancing RRC signaling to allow dynamic indication of frequency hopping for PUCCH repetition via indication of PUCCH resource.

In R1-2110204, Proposal 4: Support implicit indication of PUCCH repetition factor based on beam selection.

In R1-2110099, Proposal 1: 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.

In R1-2110240, Proposal 1: For supporting dynamic indication of the repetition factor for PUCCH repetitions in NR Rel-17 coverage enhancements, PRI table can be enhanced to map each PUCCH resource with a repetition factor.

In R1-2110240, Proposal 2: For supporting dynamic indication of the repetition factor for PUCCH repetitions in NR Rel-17 coverage enhancements, consider increasing maximum the number of PRI bits from 3 to 4 to allow more flexibility in terms of multiple repetition factors associated with each of the PUCCH resource.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Samsung | RAN1 had extensive discussion in RAN1#106-e and it was agreed to confirm the WA. That should not have happened if the WA was not sufficient or had any problem. Companies bringing new proposals at this meeting supported confirming the WA and therefore agreed that it provides all necessary functionality without any problem. We do not support any enhancements/changes to the agreement in this WI. |
| Apple | In our view, RAN1 shall discuss the exact formulation on PRI/CCE to map a PUCCH resource, at least when number of resources within a set is more than 32. Alternatively, there has to be an agreement that number of resources per set (with/without per resource repetition factor) is never more than 32. |

# 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.

## DMRS bundling scheme and signalling

### Time domain window design details

In RAN1 #106e, after a heated discussion, the following working assumption was agreed for time domain window design for DMRS bundling across PUSCH repetitions.

**Working assumption:**

For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, all the repetitions are covered by one or multiple consecutive/non-consecutive configured TDWs.

   Each configured TDW consists of one or multiple consecutive physical slots.

   The window length *L* of the configured TDW(s) can be explicitly configured with a single value~~and~~*~~L~~*~~is no longer than the maximum duration~~.

‐   FFS: The maximum value of *L* ~~is the duration of all repetitions~~

‐   FFS: Solutions to error propagation issue if ~~for~~ *L* is longer than the maximum duration is to be discussed further.

‐   FFS: The window length *L* is configured per UL BWP

   The start of the first configured TDW is the first PUSCH transmission

‐   FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.

   The start of other configured TDWs can be implicitly determined prior to first repetition.

‐   FFS: The configured TDWs are consecutive for paired spectrum/SUL band

‐   FFS: The start of the configured TDWs for unpaired spectrum is implicitly determined based on semi-static DL/UL configuration.

   The end of the last configured TDW is the end of the last PUSCH transmission.

‐   FFS: The end of the configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.

   Within one configured TDW, one or multiple actual TDWs can be implicitly determined:

‐   The start of the first actual TDW is the first PUSCH transmission within the configured TDW.

* FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.

‐   After one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.

* The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.

  FFS: The end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.

* An event occurs that violates power consistency and phase continuity

  FFS: The events may include e.g., a DL slot based on DL/UL configuration for unpaired spectrum, the actual TDW reaches the maximum duration, DL reception/monitoring occasion for unpaired spectrum, high priority transmission, frequency hopping, precoder cycling.

  FFS: The end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.

‐   If the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.

* If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event,

  FFS: The start of the new actual TDW is the first available slot/symbol for PUSCH transmission after the event.

* If UE is not capable of restarting DM-RS bundling, no new actual TDW is created until the end of the configured TDW.
* FFS: UE capability of restarting DMRS bundling is applied only to dynamic event or not

Note 1: A ‘configured TDW’ refers to a time domain window whose length can be configured to ‘L’ and whose start and end is determined as described above.

Note 2: An ‘actual TDW’ refers to a time domain window during whose entire duration the DM-RS bundling is actually applied. An ‘actual TDW’ duration is always less than or equal to the ‘configure TDW’ duration.

Note 3: Whether the terms ‘configured TDW’ and ‘actual TDW’ are revised to other terms and if such terminology is used in specifications is to be further discussed.

Since almost all companies prefer to have a common TDW(time domain window) design between PUCCH and PUSCH DMRS bundling. The following is proposed by FL

**FL proposal 1: the working assumption agreed in RAN1 106e on TDM (time domain window) in agenda 8.8.1.3 is reused for DMRS bundling for PUCCH repetitions, by replacing “PUSCH repetition/transmission” with “PUCCH repetition/transmission”.**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Nokia/NSB | Agree |
| InterDigital | Support |
| Intel | We are fine with the proposal. |
| Samsung | We think the agreement for DM-RS bundling for PUCCH should be based on an agreement for PUSCH. After the WA is confirmed (with or without any changes), we would agree to apply to PUCCH. |
| Lenovo, Motorola Mobility | Although our preference would be to wait for the confirmation of working assumption and some further details related to FFS points under PUSCH agenda, but if we want to same WA here (not yet agreement), we are okay to have it |
| QC | We are okay to extend the WA to PUCCH as well. |

### Signalling for DMRS bundling cross PUCCH repetitions

The following issue was identified in RAN1 106e. We continue to discuss this issue in RAN1 106bis-e.

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

For this open issue, based on input from companies in the submitted contributions, majority companies support not introducing additional dynamic signalling. Therefore, the following FL proposal is made.

**FL proposal 2: Dynamic signaling to enable/disable DMRS bundling for PUCCH or PUSCH repetitions is not supported in Rel-17.**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Nokia/NSB | Agree. |
| Intel | We are fine with the proposal. |
| Samsung | OK |
| Lenovo, Motorola Mobility | Support the FL proposal |
| QC | Support. |

## 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 8.8.1.3 for 8.8.2.

Based on the partition of work load between 8.8.13 FL and 8.8.2 FL, the discussion of question 3 will be conducted in 8.8.2 and the outcome of this discussion will be applied to both PUCCH and PUSCH repetitions.

The following are the discussion on this topic in RAN1 106e.

FL Question 4 (raised in RAN1 106e): 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 answers to the above FL question in RAN1 106e are collected below for information purpose.

|  |  |
| --- | --- |
| **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. |
| InterDigital | We prefer to align the design principle with DMRS bundling for frequency hopping for PUSCH. This discussion related to how a time window is configured. |

Based on the comments received in RAN1 106e, and considering the concept of both configured TDW and actual TDW are introduced, the discussion on interaction between frequency hopping and DMRS bundling for PUCCH/PUSCH can be formulated as following.

**FL proposal 3: For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, a UE perform the “hopping intervals determination”, “configured TDW determination”, and** **“actual TDW determination” in a sequential ordering. The following options of the ordering are the starting point for further study.**

* **Option 1: “hopping intervals determination” -> “configured TDW determination” -> “actual TDW determination”**
* **Option 2: “configured TDW determination” -> “hopping intervals determination” -> “actual TDW determination”**
* **Option 3: “configured TDW determination” -> “actual TDW determination” -> “hopping intervals determination”**
* **Option 4: “configured TDW determination” -> “actual TDW determination” and “hopping intervals determination”**

**Note: option 1, 2, and 3 assume a hopping internal can be different than an actual TDW. Option 4 assumes a hopping internal is the same as an actual TDW.**

**Note 2: other options are not precluded.**

**Note 3: combinations of above option 1 such as adopting one option for FDD and adopting another option for TDD are not precluded.**

Companies are welcome to provide comments and suggestions to the above FL proposal.

|  |  |
| --- | --- |
| **Company name** | **Answer/Comment** |
| Nokia/NSB | The goal of DMRS bundling is to increase channel estimation accuracy. This technique was studied during the SI with this understanding in mind, which is not only intuitive but also practically relevant. Out of the 4 proposed options, Option 4 is the one which guarantees that the largest number of DMRS can be bundled on average.  Option 1 and Option 2 will always result in poorer channel estimation accuracy, which in general brings more gain that frequency diversity.  Option 3 may provide the same results as Option 4 if hopping intervals coincide (and they could, depending on the configuration), however lower performance would be observed in other cases. For this reason, it is safe to say it would provide less stable results, and never better than Option 4.    For all these reasons, Option 4 should be preferred as more aligned with the ultimate target of this PUSCH/PUCCH enhancement. |
| InterDigital | Option 2 seems to be aligned with the TDW design. A TDW is configured, and based on hopping intervals, actual TDW is determined implicitly. Determination of actual TDWs should follow the configurations given to the UE (thus it should be the last step). |
| Intel | Our view is that inter-slot bundling size may be separately configured from TDW duration, which can provide good flexibility/balance for frequency diversity gain and channel estimation gain. So we prefer Option 1.  We have concerns on Option 3 if hopping interval duration is determined based on actual TDW determination. Given that it may be some mis-alignment between gNB and UE on the determination of actual TDW, if hopping interval duration is determined based on the actual TDW, this would introduce undesirable impact on the frequency hopping and lead to decoding failure at receiver side. |
| Samsung | The TDW length is the time duration of the frequency hop when frequency hopping is configured. In case the TDW length is also provided (and can’t be larger than the duration of the frequency hop), UE would use it. Then other constraints apply if an event occurs, as discussed in AI 8.8.1.3 for PUSCH. |
| Lenovo, Motorola Mobility | We are fine with either option 2 or option 4. Basically, both options ensure that the actual TDW duration will always be less than or equal to the hopping interval duration. Based on simplicity that actual TDW and hopping interval are determined simultaneously in option 4, we can slightly prefer option 4.  Minor type in the note:  **Note 1: option 1, 2, and 3 assume a hopping inter~~n~~val can be different than an actual TDW. Option 4 assumes a hopping inter~~n~~val is the same as an actual TDW.** |
| QC | Option 1 is the only way to make sure the gNB is able to allocate resources in an efficient manner across users when frequency hopping is enabled. Ill-fitting hop patterns across users will lead to resource wastage.  Even in the current spec, hopping is tied to physical slot indices (odd/even), and not impacted by when a UE is scheduled to transmit PUSCH. This same principle should continue to be observed. Cell-level resource efficiency should be an important consideration. |

## Other proposals

R1-2110125 studied the sensitivity of DMRS bundling to imperfect phase continuity and provided simulation results. Companies are encouraged to check the simulation results provided and consider the need to study the techniques of gNB phase error compensation.

Regarding the issue of PUCCH with repetition/DMRS bundling overlap with other PUCCH without repetition/DMRS bundling, R1-2110049 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.

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Samsung | Rel-16 specifications are sufficient. The only change in Rel-17 is that the number of repetitions for a PUCCH with HARQ-ACK can be part of the PUCCH resource instead of being same for all PUCCH resources. That is not a reason for changing the Rel-16 UE behavior for overlapped PUCCHs. |
| Apple | To Samsung: we are puzzled with “Rel-16 specifications are sufficient”: we do NOT have DMRS bundling in R15/16. The issue here is that at least one PUCCH with DMRS bundling is dropped. Open questions are on UE behavior/expectation, for example: should DMRS bundling being terminated, or resume for the rest of repetitions… These open aspects at least need to be discussed and concluded. |
|  |  |

# Power control and TA with PUCCH repetitions

Based on companies input in contributions, we could strive for a common design of power control and TA handling for PUCCH and PUSCH repetitions. Therefore, we could hold on the discussion on this topic until progress made in agenda 8.8.1.3.

# References

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| --- | --- | --- |
| [R1-2108741](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2108741.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2108848](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2108848.zip) | Discussion on coverage enhancements for PUCCH | ZTE |
| [R1-2108922](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2108922.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2108992](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2108992.zip) | Discussion on PUCCH enhancements | vivo |
| [R1-2109091](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109091.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2109243](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109243.zip) | Discussion on PUCCH enhancement | CATT |
| [R1-2109251](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109251.zip) | Remaining issues on PUCCH enhancements | China Telecom |
| [R1-2109298](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109298.zip) | Discussion on PUCCH enhancements | CMCC |
| [R1-2109427](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109427.zip) | Discussion on PUCCH enhancements | Xiaomi |
| [R1-2109457](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109457.zip) | Discussion on PUCCH enhancement for NR coverage enhancement | Panasonic Corporation |
| [R1-2109507](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109507.zip) | PUCCH enhancements | Samsung |
| [R1-2109627](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109627.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2109695](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109695.zip) | PUCCH enhancements for coverage enhancement | NTT DOCOMO, INC. |
| [R1-2109814](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109814.zip) | PUCCH enhancements | ETRI |
| [R1-2109889](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2109889.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [R1-2110003](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110003.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2110049](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110049.zip) | PUCCH coverage enhancement | Apple |
| [R1-2110099](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110099.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2110125](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110125.zip) | PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [R1-2110155](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110155.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2110204](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110204.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2110240](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106b-e/R1-2110240.zip) | Enhancements for PUCCH repetition | Lenovo, Motorola Mobility |