**3GPP TSG RAN WG1 #107bis-e R1-22xxxxx**

**e-Meeting, Jan 17th – 25th, 2022**

**Agenda item:** 8.8.2

**Source:** Moderator (Qualcomm)

**Title:** FL summary #1 of PUCCH coverage enhancement

**Document for:** Discussion/Decision

# Introduction

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

# RRC parameters for PUCCH repetitions

## Proposals discussed in RAN1 107e

First of all, FL would like to remind every company that we need to finalize RRC related aspects in this meeting. Therefore, FL suggest companies to be more constructive and flexible on RRC related issues.

**RRC parameter “PUCCH-nrofSlots-r17”**

The following FL proposal was almost agreeable in RAN1 107e expect one company had some concerns. FL would like to check if the concern still remains. If so, how can we address the concern to wrap up this issue.

**FL proposal 1: In column J of RRC parameter “PUCCH-nrofSlots-r17”, add a note as the following:**

* **Note: a PUCCH resource not configured with PUCCH-nrofSlots-r17 can attain the value of 1 according to when the Rel-15/16 parameter nrofSlots is not configured.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Support |
| Intel | We are fine with FL proposal 1. |
| vivo | Fine with the FL proposal. |
| Sharp | Support |
| Panasonic | We are fine with the FL proposal 1. |
| CATT | Agree. |
| LG | Support FL’s proposal. It is our understanding that the case when both of PUCCH-nrofSlots-r17 and nrofSlots are not configured, PUCCH is not repeated. |
| NTT DOCOMO | Fine with the proposal. |
| Apple | Support |
| China Telecom | Generally fine, suggest to refine the wording as “if a PUCCH resource is not configured with *PUCCH-nrofSlots-r17* or Rel-15/16 parameter *nrofSlots*, then the value is 1”. |
| Samsung | Can accept |
| Ericsson | We agree with the FL that this is an important issue to resolve. It should be clear to RAN2 that RAN1’s intention is to enable the value of 1 by some mechanism, which is not necessarily so with the current value range and parameter description. Whether a parameter value is directly configured or default values are used in ASN.1 when a parameter is conditionally present should be RAN2’s decision ultimately. That RAN1’s intention is to allow a dynamic value of 1 to be selected may not be immediately clear to RAN2, and so we think it is beneficial to add the note. Then if RAN2 instead decides it is better to be able to configure a value of 1 than to not configure PUCCH-nrofSlots-r17 for a resource to allow dynamic indication of a repetition factor of 1, they can do so. |
| ZTE | Fine with the proposal. |
| CMCC | Fine with the FL proposal 1. |
| Lenovo, Motorola Mobility | We are fine with the proposal |
| Spreadtrum | Fine with FL proposal. |
| Xiaomi | Fine with FL’s proposal |
| OPPO | OK for the note. |
| Huawei, HiSilicon | Support. |

**RRC parameter “PUCCH-DMRS-Bundling”**

In last RAN1 meeting, we narrow down to the following two options.

* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH resource format**

A down-selection (maybe a hard binary decision) has to be made in this meeting between these two options. Before that, FL would like to collect companies’ views/votes as below.

**FL question 1: which one of the below two options should be supported, and why?**

* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH resource format**

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| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2 | As per existing agreements, we should strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible. Exception could exist of course, but we do not see a valid technical use case to justify such exception for this aspect. |
| Intel | Option 2 | As previously mentioned, if this is configured per PUCCH resource format and when a new PUCCH resource is generated for overlapped dynamic HARQ-ACK and CSI, this would mean dynamic enabling/disabling DMRS bundling for PUCCH repetition, which is against the previous agreement. |
| Sharp | Option 2 | It was agreed that dynamic signaling/adaptation to enable/disable DMRS bundling for PUCCH repetition is not supported in Rel-17. |
| Panasonic | Option 2 | Since PUCCH resource/format can be dynamically changed, Option 3 means dynamic indication of enabling/disabling DMRS bundling is supported. Since dynamic indication is not supported for PUSCH, to have unified operation (i.e., only semi-static configuration) is better. |
| CATT | Option 2 | Additionally, *PUCCH-DMRS-Bundling* does not apply to PUCCH format 0, since it is sequence-based and without DMRS. |
| LG | Prefer option 2. | Considering the previous agreement in RAN1#105-e that “strive for common design of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible”, DMRS bundling of PUCCH should be remained to be same with that of PUSCH unless there is a critical issue.  For the common design between DMRS bundling of PUSCH and PUCCH, “PUCCH-DMRS-Bundling” should be per UL BWP which is aligned to DMRS bundling for PUSCH. |
| Apple | Option 3 | UE will not be able to apply DMRS bundling on (at least) short PUCCH formats |
| China Telecom | Option 2 |  |
| Samsung | Option 2 | There is no meaningful use case for per PUCCH resource – no need to complicate the design. |
| Ericsson | Option 3 is our first choice. | As was pointed out in the RAN1#107 email discussions, Rel-17 UL multi-TRP supports diversity across repetitions, and we think that it may make sense to configure it differently for e.g. short and long PUCCH formats, possibly to support URLLC and non-URLLC applications. |
| QC | Option 3 | For short formats, diversity is more important than bundling. This is important for FR2 operation. |
| ZTE | Prefer Option 2 |  |
| CMCC | Option 2 | As what we have agreed, dynamic signaling/adaptation to enable/disable DMRS bundling for PUCCH repetition is not supported. To strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible, option 2 should be support. The PUCCH format 0 is absent, because it is sequence-based and DMRS-less. |
| Lenovo, Motorola Mobility | Option 2 | Common design is strived for both PUSCH and PUCCH |
| Spreadtrum | Prefer Option 3 | A common parameters may not be suitable for all PUCCH formats, since their coverage requirements are different. A finer granularity is preferred. |
| Xiaomi | Option 2 | Common design is strived for PUSCH/PUCCH with DMRS bundling as much as possible |
| OPPO | Option 2 | Per BWP is better for sharing same design of PUSCH. |
| Huawei, HiSilicon | Option 2 | Agree with Nokia. |

**RRC parameter “PUCCH-TimeDomainWindowLength”**

In last RAN1 meeting, we narrow down to the following two options.

* **Option 2: The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-TimeDomainWindowLength” is per PUCCH resource format**

A down-selection (maybe a hard binary decision) has to be made in this meeting between these two options. Before that, FL would like to collect companies’ views/votes as below.

**FL question 2: which one of the below two options should be supported, and why?**

* **Option 2: The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**
* **Option 3: The RRC parameter “PUCCH-TimeDomainWindowLength” is per PUCCH resource format**

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| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2 | See above. |
| Intel | Option 2 | Same comment for PUCCH-DMRS-Bundling |
| Sharp | Option 2 | In AI 8.8.1.3, it was agreed that the window length L is configured per UL BWP and we should strive for common design as much as possible. |
| Panasonic | Option 2 | Since PUCCH resource/format can be dynamically changed, Option 3 means dynamic indication of window length of configured TDW is supported. Since there was a conclusion that dynamic indication of the window length of the configured TDW by DCI is not supported, we think Option 2 is aligned to this conclusion. |
| CATT | Option 2 | Additionally, *PUCCH-DMRS-Bundling* does not apply to PUCCH format 0, since it is sequence-based and without DMRS. |
| LG | Prefer option 2. | Same comment with previous question. |
| NTT DOCOMO | Option 3 | We prefer “PUCCH-TimeDomainWindowLength”, (or “PUCCH-DMRS-Bundling”) can be configured per PUCCH resource format, since the required length for the DMRS bundling for long/short PUCCH format may be different with considering e.g. different TDD pattern. |
| Apple | Option 2 | No need to go with more granular option 3 (and TDW configuration can be independent of DMRS bundling) |
| China Telecom | Option 2 |  |
| Samsung | Option 2 | There is no meaningful use case for per PUCCH resource – no need to complicate the design. |
| Ericsson | Option 3 is sufficient. | Since the time domain window length is dependent on RF behaviors that change on the order of 10s of milliseconds or more rather than on channel format, there does not seem to be a motivation to configure it per PUCCH format, nor to change it rapidly. |
| QC | Option 3 | Bundling parameters could be different between short and long formats. |
| ZTE | Prefer Option 2 |  |
| CMCC | Option 2 | As we have discussed in the last meeting, in Rel-15/16, The IE PUCCH-Config, which is used to configure UE specific PUCCH parameters, is per UL BWP. So it seems inconvenient and unnecessary to use a finer granularity to configure DMRS bundling. For joint channel estimation used in PUSCH, the window length *L* is configured per BWP |
| Lenovo, Motorola Mobility | Option 2 | Same as above |
| Spreadtrum | Prefer Option 3 | Same as above |
| Xiaomi | Option 2 |  |
| OPPO | Option 2 |  |
| Huawei, HiSilicon | Option 2 | Same as above |

Companies input are summarized as below.

**For RRC parameter “PUCCH-DMRS-Bundling”**

* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP**
  + **Supporting companies: Nokia/NSB, Intel, Sharp, Panasonic, CATT, LG, CT, Samsung, ZTE**
* **Option 3: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH resource format**
  + **Supporting companies: Apple, Ericsson, QC**

**For RRC parameter “PUCCH-TimeDomainWindowLength**

* **Option 2: The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**
  + **Supporting companies: Nokia/NSB, Intel, Sharp, Panasonic, CATT, LG, Apple, CT, Samsung, ZTE**
* **Option 3: The RRC parameter “PUCCH-TimeDomainWindowLength” is per PUCCH resource format**
  + **Supporting companies: DCM, Ericsson, QC**

It is clear majority prefer option 2 for both RRC parameters. FL suggest to take majority view to settle down this issue.

**FL proposal 1a: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP. The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Huawei, HiSilicon | Supports. |
| CATT | Support. |
| Nokia/NSB | Support |
| Intel | Support |
| Ericsson | The concerns with per PUCCH format configuration for DMRS bundling often seem to be the agreement below.  **Agreement**  **Dynamic signaling to enable/disable DMRS bundling for PUCCH or PUSCH repetitions is not supported in Rel-17.**  In our view, the intent of this agreement was that dynamic signaling would not be introduced specifically to support dynamic changes in UE state or channel conditions. Support for such changes in was not needed in our view given the short sizes of time domain windows and since such dynamic changes would add unneeded scheduling complexity. Allowing bundling to be configured differently for different PUCCH formats does not seem to conflict with this intent, and would support use cases with different configurations between PUCCH formats such as where M-TRP PUCCH repetition would be configured to support URLLC and non-URLLC applications.  So our first preference continues to be to support bundling per PUCCH format. On the other hand, the majority view expressed so far is clear, and we will not oppose FL proposal 1a. |
| Panasonic | Support |
| Sharp | Support |
| NTT DOCOMO | We prefer the compromised solution proposed by Qualcomm in GTW. On the other hands, we can live with the FL proposal with majority view. |
| QC | This is not acceptable to us. We offered a fair compromise during the GTW session. Can we configure window length at the BWP granularity while going with per format for enabling/disabling DMRS bundling?  Our motivation is rather straightforward --- for short formats with repetition, the motivation could be beam sweeping or antenna switching. The intent here is diversity and imposing phase continuity could end up counterproductive. Lets let network operators/planners decide what is best for each format. |
| LG | Support. |

### Second round discussion

**Updated** **FL proposal 1a: down-select from the following two options in RAN1#107bis-e.**

* **Option 1: The RRC parameter “PUCCH-DMRS-Bundling” is per UL BWP. The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP.**
* **Option 2: The RRC parameter “PUCCH-DMRS-Bundling” is per PUCCH format. The RRC parameter “PUCCH-TimeDomainWindowLength” is per UL BWP**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Lenovo, Motorola Mobility | Support the FL proposal 1a |
| LG | Support option 1. |
| Huawei, HiSilicon | A common design for PUSCH/PUCCH with DMRS bundling is preferred. So option 1 is preferred. |

## New proposals

R1-2200153 Proposal 3: Inter-bundling frequency hopping can be explicitly configured for PUSCH and PUCCH via introducing a new candidate alternative in frequency hopping configuration related IEs in PUSCH-Config and a new frequency hopping IE in PUCCH-FormatConfig, respectively.

R1-2200502 Proposal 3: Hopping interval for PUCCH should be configured per UL BWP.

R1-2200488 Proposal 2: Adopt the following table for the RRC parameters for PUCCH and PUSCH frequency hopping interval.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **Per (UE, cell, TRP, …)** | **UE-specific or Cell-specific** |
| NR\_cov\_enh-Core | DM-RS bundling for PUCCH | *PUCCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUCCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,  ENUMERATED {1, 5, 10, 20} for unpaired spectrum | *PUCCH-TimeDomainWindowLength* | in PUCCH-Config | UE-specific |
| NR\_cov\_enh-Core | DM-RS bundling for PUSCH | *PUSCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUSCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,  ENUMERATED {1, 5, 10, 20} for unpaired spectrum | *PUSCH-TimeDomainWindowLength* | in PUSCH-Config | UE-specific |

Given we have to finalize the RRC parameters related design in this RAN1 meeting, on this issue, FL would like to kick off the discussion directly based on R1-2200488 Proposal 2, which is a very comprehensive proposal already.

**FL question 3: What is your feedback/comment to the following proposal:**

**R1-2200488 Proposal 2: Adopt the following table for the RRC parameters for** **PUCCH and PUSCH frequency hopping interval.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **WI code** | **Sub-feature group** | **Parameter name in the spec** | **New or existing?** | **Description** | **Value range** | **Default value aspect** | **Per (UE, cell, TRP, …)** | **UE-specific or Cell-specific** |
| NR\_cov\_enh-Core | DM-RS bundling for PUCCH | *PUCCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUCCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,  ENUMERATED {1, 5, 10, 20} for unpaired spectrum | *PUCCH-TimeDomainWindowLength* | in PUCCH-Config | UE-specific |
| NR\_cov\_enh-Core | DM-RS bundling for PUSCH | *PUSCH-Frequencyhopping-Interval* | New | Number of consecutive slots for UE to perform inter-slot frequency hopping with inter-slot bundling for PUSCH | ENUMERATED {1, 2, 4, 8} for paired spectrum and SUL band,  ENUMERATED {1, 5, 10, 20} for unpaired spectrum | *PUSCH-TimeDomainWindowLength* | in PUSCH-Config | UE-specific |

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | The spirit of the proposal is fine with us; however, we think that a decision on the value range should be made after we finalize the discussion in Section 4.2, i.e., details on how frequency hopping intervals are determined. |
| Intel | We are generally fine with the proposal. However,   * It is not clear to us whether we need consecutive. Suggest to remove “Number of ~~consecutive~~ slots” * for the default value, we need to first reach consensus for bundling size first. |
| Vivo | We are fine to add these two parameters.  While the value range should be FFS, in our understanding, the same value range for the interval can be applied for both TDD/FDD.  Besides, for PUCCH, *PUCCH-Frequencyhopping-Interval* should be configured per PUCCH resource*.* |
| Sharp | We are generally fine with the proposal but suggest to change “inter-slot bundling” in description to “DMRS bundling”. |
| Panasonic | The value rage of {1, 5, 10, 20} for unpaired spectrum should be starting point of discussion. The length of frequency hopping interval and configured TDW should support the length aligned with *dl-UL-TransmisisonPeriodicity*, which takes the value of {ms0p5, ms0p625, ms1, ms1p25, ms2, ms2p5, ms5, ms10} and {ms3, ms4}. This is because if hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. {1, 5, 10, 20} for unpaired spectrum can support the length aligned with the value of {ms0p5, ms0p625, ms1, ms1p25, ms2, ms2p5, ms5, ms10}. |
| CATT | Generally fine with the proposal.  Preferably, candidate numbers for hopping interval should be unified between paired (& SUL) and unpaired spectrums. |
| LG | Before introducing RRC parameter, it should be discussed that the hopping intervals for PUCCH/PUSCH repetitions with DMRS bundling is derived based on parameters or configured by new RRC parameters, which is represented in FL question 8. Moreover it is quite unclear to us that why “1” should be supported for the value range since it is equivalent to the Rel-17 frequency hopping. |
| NTT DOCOMO | We are fine with the proposal. |
| Apple | Support the intention |
| China Telecom | Support. Regarding Intel’s comments, we think the counting of hopping interval is better to be based on physical slots, which is a simple solution. Thus, we prefer “Number of consecutive slots”. For the value range and default value, we think explicit discussion is needed, we are fine to made the decision after we finalize the discussion in Section 4.2. |
| Samsung | This should be discussed after completion of the frequency hopping discussion. |
| Ericsson | We are OK to have different hopping intervals for PUCCH and PUSCH. However, we think that it is important to reap the gains from the new frequency hopping design as often as possible. For TDD, where coverage gains are generally most needed, commonly there may be two or no back to back UL slots, and so no gain from DMRS bundling. However, frequency hopping can provide gains where DMRS bundling provides little or no gains. Therefore before agreeing to this proposal, we would like to have some conclusions on the frequency hopping design in section 4.2. |
| QC | Okay to introduce the parameters. But the value ranges can be left out for now.  Prefer to introduce it per format for PUCCH. Please leave last before column as FFS. |
| ZTE | Regarding the value range, we propose to add ‘16’ for paired spectrum and SUL band to achieve only one FH in case of a maximum number of repetitions with 32, and to add ‘4’ and ‘8’ for unpaired spectrum to accommodate TDD configuration of ‘DDSU’ used in FR2.  Regrading the default value, it also depends on the discussion in section 4.2.3. |
| CMCC | Basiclly fine with this proposal, and the value range should be FFS. |
| Lenovo, Motorola Mobility | Generally fine with proposal, but exact values can be discussed later for each PUCCH formats |
| Spreadtrum | Can accept, and values should be further discussed. |
| Xiaomi | General fine with the proposal, value range needs further discussion. |
| OPPO | We actually propose to drive the Hopping interval can be derived by the repetition number of slot. Simply say, half of the repetition. This will save the RRC parameter and the candidate value discussion.  If have to set the parameter, we prefer to simply have 1, 2, 4, 8. |

Reading input received so far, most of the companies are OK to introduce these two new RRC parameters for frequency hopping. The details such as value range could be FFS. Therefore, FL make the follow proposal.

**FL proposal 1b: For PUCCH repetitions and PUSCH repetitions with DMRS bundling, introduce the following two RRC parameters for frequency hopping interval configuration.**

* **PUCCH-Frequencyhopping-Interval**
* **PUSCH-Frequencyhopping-Interval**

**Note: finalize the details (such as value range, parent IE, etc…) of these two RRC parameters in RAN1 107#bis-e.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CATT | Support. |
| Nokia/NSB | Support |
| China Telecom | Support. |
| Intel | Support |
| Ericsson | Support |
| Samsung | Parameters should be optional. |
| Panasonic | Support |
| Sharp | Support |
| Lenovo, Motorola Mobility | Support |
| LG | Support. |
| Huawei, HiSilicon | Support |

# Dynamic PUCCH repetition factor indication

## Dynamic PUCCH repetition factor indication for HARQ-ACK of first SPS PDSCH associated with the activation DCI and SPS release DCI

Regarding whether dynamic PUCCH repetition factor indication is applicable to HARQ-ACK for first SPS PDSCH associated with the activation DCI and SPS release DCI, the following FL conclusion was proposed in RAN1#106bis.

FL proposed conclusion 1: In NR Rel-17, for HARQ-ACK for SPS PDSCH, it is clarified that the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e applies to HARQ-ACK corresponding to the SPS release DCI

* FFS whether dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for the first SPS PDSCH associated with the activation DCI.

However, it was not agreeable in RAN1 107e mainly due to controversial views on the FFS. A few companies think the FFS is actually a Rel-15 maintenance issue.

Given Rel-15 maintenance should be handled in other AI, therefore, the following FL proposal is made to capture the current situation of the discussion and wrap up this topic.

**FL proposal 2: In NR Rel-17, for HARQ-ACK for SPS PDSCH, it is clarified that the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e applies to HARQ-ACK corresponding to the SPS release DCI**

* **Note: It is still open whether dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for the SPS activation DCI. Several companies request clarification of Rel-15/16 spec before resolving this open issue.**

Comments to the above FL proposal can be provided in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | In our view, SPS activation DCI and SPS release DCI are part of the same “family” of DCI. They are both not associated to a PDSCH (since the latter is configured via RRC). We are not comfortable with the idea of decoupling the two issues, since this would create even more confusion. If this is what it takes, let us clarify Rel-15/16 spec first. |
| Intel | We are fine to make conclusion for the SPS release DCI, which should be not controversial. However, for activation DCI, clarification on Rel-15 behavior is needed and our view is that this is based on PRI + CCE to determine the PUCCH resource.  We suggest to also make conclusion that dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH which is not associated with or activated by a DCI is not supported |
| Panasonic | We are fine with FL proposal 2. |
| CATT | OK. As well explained by Apple in the previous meeting, this is an issue left over from history. Although after exchanging views in several rounds, we think SPS activation DCI should be viewed as dynamic grant. So dynamic PUCCH repetition factor indication will be applied to HARQ-ACK SPS activation DCI by natural, without spec change. |
| Apple | We are not comfortable with the note. Dynamic indication of repetition factor is applied to PUCCHs associated with DCI, and PUCCH carrying HARQ-ACK for activation SPS PDSCH, or SPS release, IS associated with DCI. |
| Samsung | Do not agree. It is surprising to see this FL proposal again in CovEnh – this is not a CovEnh issue. In Rel-15, the PUCCH resource for HARQ-ACK is the one configured by RRC, not the one indicated by PRI. We are not aware of any UE implementation in the field that does not use the RRC configured resource. Proponents can bring a Rel-15 CR to suggest changing the resource allocation for HARQ-ACK for SPS PDSCH or to discuss any need to clarify. |
| Ericsson | We’d like to check the common understanding for the SPS release case. From 38.213 section 9.1, we have:  If a UE is configured to receive SPS PDSCH(s) in a slot for SPS configuration(s), the UE does not expect to receive a PDCCH providing a DCI format in the slot to indicate SPS PDSCH release of these SPS configuration(s), if HARQ-ACK information for the SPS PDSCH release and the SPS PDSCH reception(s) would map to different PUCCHs.  So our understanding is that the HARQ-ACK for SPS release uses the same PUCCH resource as for the SPS PDSCH, if SPS release is given without scheduling a DG PDSCH. Then since dynamic repetition is not supported for the PUCCH resource for SPS PDSCH configured in SPS-Config, it doesn’t seem that it should be supported for HARQ-ACK for SPS release in this ‘SPS-only’ case. However, if a DG PDSCH is scheduled and the corresponding HARQ-ACK is transmitted with the HARQ-ACK for DL SPS release, the PUCCH resources for DG are used. In that case, dynamic PUCCH repetition is applicable.  Regarding the note, there is no HARQ-ACK for the SPS activation DCI itself (unlike SPS release), although there is HARQ-ACK for the PDSCH that is in turn transmitted in response to the activation DCI. However, if a DG PDSCH is scheduled, then the PUCCH resources for DG are used if the DG HARQ-ACK is transmitted simultaneously with the SPS HARQ-ACK.  So overall we propose the following clarification to proposal 2:  **FL proposal 2: In NR Rel-17, for HARQ-ACK for SPS PDSCH, it is clarified that the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e applies to HARQ-ACK corresponding to the SPS release DCI and a DG PDSCH when transmitted together**   * **Note: It is still open whether dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for an SPS PDSCH transmitted in response to the SPS activation DCI. Several companies request clarification of Rel-15/16 spec before resolving this open issue** |
| ZTE | Fine with the proposal in general.  Regarding the note, ‘HARQ-ACK for the SPS activation DCI’ should be replaced by ‘HARQ-ACK for SPS PDSCH associated with the SPS activation DCI’. In our view, the SPS PDSCH associated with the SPS activation DCI is the same as dynamic PDSCH according to legacy rules. |
| CMCC | Fine with the FL proposal 2. |
| Xiaomi | Fine with the FL’s proposal |
| OPPO | OK with the proposal 2. |
| Huawei, HiSilicon | OK. |

## Other proposals

There are a few other proposals in submitted contributions to this agenda, which are listed as below.

R1-2200423 Proposal 2: 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

FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 2.1 and 2.2. But companies are welcome to provide comments to the above proposals in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Apple | We are fine with FL’s assessment to discuss this issue later, although we should note that without any specification/conclusion/etc in that regard the Rel-17 spec is broken for A) resource set0 with number of PUCCH resources more than 32 B) other resource sets with number of resources more than 8. Thus, some RAN1 discussions to have (at least) conclusions on UE behavior/expectation is anyway needed |
| Samsung | No need to discuss. |
| Huawei, HiSilicon | It is not necessary. |
|  |  |

# 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.

## PUCCH TDW design details

In RAN1 107e, the following agreement was made.

**Agreement**

**For PUCCH DMRS bundling, when appliable, reuse the procedure developed for PUSCH DMRS bundling to determine configured TDW(s) and actual TDW(s).**

* **FFS: events for PUCCH actual TDW(s)**

On the FFS, the input from companies are the following.

R1-2200054 Proposal 1: The agreed events for PUSCH actual TDWs should be also applicable to PUCCH actual TDW.

* Dropping/cancellation based on Rel-15/16 collision rules;
* DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum;
* Other uplink transmission in the middle of two PUSCH/PUCCH transmissions;
* Gap between two PUSCH/PUCCH transmissions exceeds 13 symbols;
* TA adjustment;
* Frequency hopping;
* UL beam switching for multi-TRP operation.

R1-2200468 Proposal 1: Same events can be reused and defined for PUCCH actual TDW(s)

R1-2200089 Proposal 11: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event.

R1-2200614: Proposal 1: The configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH.

Given CR R1-2112967 actual captured the events which would break the power consistency and phase continuity for PUCCH/PUSCH repetitions, FL’s initial assessment is that the proposal in R1-2200054 and R1-2200468 are already captured in Rel-17 specification.

Next, FL would like to collect comments/feedback to R1-2200089 Proposal 11 and R1-2200614 Proposal 1.

**FL question 4: What is your view/feedback to the following two proposals**

**R1-2200089 Proposal 11: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Ok. |
| Intel | We are fine with the proposal. |
| vivo | Support this proposal. |
| Sharp | Support |
| Panasonic | We support the proposal. |
| CATT | OK. |
| LG | According to the definition of event, i.e., events which cause power consistency and phase continuity not to be maintained, PUCCH repetition with different sets of power control parameters in multi-TRP operation should be an event. Since the UE behavior is different whether it is dynamic or semi-static event, it needs to be clarified. |
| Samsung | Although Rel-17 M-TRP supports repetitions, the framework is not same as for Rel-17 coverage enhancements (e.g. for TDW). There is no need to incorporate Rel-17 M-TRP in the Rel-17 as the structure/functionality is not compatible. |
| Ericsson | Support; this is consistent with what has been done for the case with UL beam switching for multi-TRP. |
| QC | Support. |
| ZTE | Fine with the proposal. |
| CMCC | Ok. |
| Lenovo, Motorola Mobility | Support the proposal |
| Spreadtrum | Support |
| Xiaomi | Support |
| OPPO | OK |
| Huawei, HiSilicon | OK. But more important discussion point seems about whether it is categorized as dynamic event or semi-static event. |

Based on feedback from companies, it is reasonable to add this event in the list of events that would break the power consistency and phase continuity for PUCCH/PUSCH repetitions.

**FL proposal 3: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Huawei, HiSilicon | OK. But more important discussion point seems about whether it is categorized as dynamic event or semi-static event. |
| CATT | OK. |
| Ericsson | Support |
| Sharp | Support |
| LG | OK. |

**R1-2200614: Proposal 1: The configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Nokia/NSB | Agree with the spirit of the proposal but the wording needs to be improved to avoid confusion. Suggest the following: “*The configured TDW determination procedure for the PUCCH should only be based on counting on the slots determined as available for the PUCCH and reuse the logic of the configured TDW determination procedure based on the available slot of the PUSCH*”. |
| Intel | We are fine with the proposal.  We suggest to add if applicable to the proposal.  **If applicable, the configured TDW determination of the PUCCH should reuse the configured TDW determination based on the available slot of the PUSCH,** |
| vivo | Similar with as Nokia. |
| Sharp | Support. However, it is already captured in Rel-17 specification. |
| Panasonic | We support the proposal. |
| CATT | OK. |
| LG | Support. |
| InterDigital | Support the FL’s proposal. |
| China Telecom | Generally fine with the proposal. |
| Samsung | This proposal is not clear. |
| Ericsson | We are OK with the proposal. However, PUSCH-TimeDomainWindowLength is in consecutive slots, and we don’t see why this should be different for PUCCH. Therefore, as FL proposed last meeting, we think PUCCH-TimeDomainWindowLength should be in units of consecutive slots |
| QC | Agree with the spirit. Not clear if it is necessary though. |
| ZTE | Fine with the proposal. |
| CMCC | Support this proposal. |
| Lenovo, Motorola Mobility | Support the proposal |
| Spreadtrum | Support |
| Xiaomi | Support |
| OPPO | Agree |
| Huawei, HiSilicon | Support. Nokia’s version looks better. |
| FL | @Panasonic, can you please point to us the spec text that already captured the proposal then we can close this issue. |
| Sharp | @FL,  Thank you for the comment to us(?). We point the spec text that already captured the proposal below.   |  | | --- | | 38.214-h00  6.1.7  …  - For PUSCH transmission of a PUSCH repetition Type A scheduled by DCI format 0\_1 or 0\_2 and PUSCH repetition Type A with a configured grant, when *AvailableSlotCounting* is enabled, and for TB processing over multiple slots:  - The start of the first nominal TDW is the first slot determined for the first PUSCH transmission.  - The end of the last nominal TDW is the last slot determined for the last PUSCH transmission.  - The start of any other nominal TDWs is the first slot determined for PUSCH transmission after the last slot determined for PUSCH transmission of a previous nominal TDW.  - For PUSCH transmissions of a PUSCH repetition type A scheduled by DCI format 0\_1 or 0\_2 and PUSCH repetition Type A with a configured grant, when the UE is not configured with *AvailableSlotCounting* or when *AvailableSlotCounting* is disabled, and for PUSCH repetition type B:  - The start of the first nominal TDW is the first slot for the first PUSCH transmission.  - The end of the last nominal TDW is the last slot for the last PUSCH transmission.  - The start of any other nominal TDWs is the first slot after the last slot of a previous nominal TDW.  - For PUCCH transmissions of a PUCCH repetition:  - The start of the first nominal TDW is the first slot determined for the first PUCCH transmission.  - The end of the last nominal TDW is the last slot determined for the last PUCCH transmission.  - The start of any other nominal TDWs is the first slot determined for PUCCH transmission after the last slot determined for PUCCH transmission of a previous nominal TDW. |   When *AvailableSlotCounting* is enabled, the configured TDW determination of PUSCH is based on slots “determined” for PUSCH transmissions (i.e., available slots). Likewise, the configured TDW determination of PUCCH is based on slots “determined” for PUCCH transmission, not slots for PUCCH transmissions. Therefore, it is already captured that the configured TDW determination of the PUCCH reuses the configured TDW determination based on the available slot of the PUSCH. |

### Second round discussion

**FL proposal 3: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as an event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions.**

The FL proposal 3 seems quite stable. Huawei had a comment that it should be further discussed whether the event should be categorized as dynamic event or semi-static event.

**FL question 4a: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be categorized as dynamic event or semi-static event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions?**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CATT | In 8.8.1.3, it is also discussing whether UL beam switching for multi-TRP operation is viewed as a semi-static or dynamic event. The majority thinks it can be viewed as semi-static.  Similarly, if power control difference in m-TRP is predictable, and no mis-alignment will happen between the network and UE, we prefer to categorize it as semi-static. |
| Nokia/NSB | **Semi-static**. Different set of power control parameter is used for mTRP scenario wherein one set of power control is used for one TRP. Hence, the scenario here is that one TRP scheduling the PUSCH/PUCCH repetitions, but multiple TRPs will be used for transmissions of the repetitions. Whenever a UE receives transmission from a different TRP, it needs to switch the UL beam. |
| vivo | Semi-static, similar view as CATT. |
| Ericsson | Semi-static seems appropriate: for M-TRP repetition, the pattern is fixed and known prior to the first transmission of a repeated PUCCH. |
| Panasonic | Same categorization as PUSCH multi-TRP operation should be taken. |
| Sharp | UL beam switching for multi-TRP operation is one of semi-static events because it is determined before first PUCCH transmission scheduled by DCI like frequency hopping. |
| NTT DOCOMO | We prefer to follow the outcome of 8.3.1.3 for multi-TRP operation. |
| OPPO | Consider it as semi-static. |
| ZTE | Ok with semi-static event to align with the case for UL beam switching. |
| Lenovo, Motorola Mobility | Semi-static event |
| LG | We also think it is semi-static event. |
| Huawei, HiSilicon | Semi-static. |

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 107e, the following agreement was made for inter-slot frequency hopping.

**Agreement**

For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, a UE performs the “hopping intervals determination”, “configured TDW determination”, and “actual TDW determination” in a sequential ordering, based on the following option 1.

* Option 1: “hopping intervals determination” -> “configured TDW determination” -> “actual TDW determination”
  + DMRS bundling shall be restarted at the beginning of each frequency hop
  + DMRS bunding is per actual TDW
  + FFS: Frequency hopping pattern is determined by physical slot indices.
    - FFS: different FH pattern determination for PUCCH and PUSCH
    - FFS: details of FH pattern design
  + Support separate RRC configuration(s) for hopping interval and configured TDW length.
    - if hopping interval is not configured, the default hopping interval is the same as the configured TDW length
      * FFS: if both hopping interval and TDW length are not configured
    - Note: hopping interval is only determined by the configuration of hopping interval if hopping interval is configured

There are still three FFS that need to be address. Companies’ input for each FFS are summarized as following.

### FFS: different FH pattern determination for PUCCH and PUSCH

R1-2200054 Observation 1: It seems not a critical issue to have different FH pattern for PUCCH and PUSCH.

R1-2200153 Proposal 2: Frequency hopping patterns for both PUCCH and PUSCH are determined based on physical slot indices separately.

R1-2200163 Proposal 1: Frequency hopping pattern is not determined by physical slot indices, and a UE configured for DM-RS bundling determines the frequency hopping intervals for a set of PUCCH/PUSCH transmissions based at least on the starting slot of the set of PUCCH/PUSCH transmissions for which DM-RS bundling is activated

R1-2200208 Proposal 1: For DMRS bundling for PUCCH transmission with repetitions, the frequency hopping pattern is determined based on a relative slot index as in Rel-16.

R1-2200239 Proposal 1: Available slot should be used for determination of FH pattern for PUCCH and PUSCH (counting based on available slots), if hopping interval is not configured.

R1-2200304 Proposal 2: Frequency hopping pattern for DMRS bundling across PUCCH transmissions is determined based on physical slot indices.

R1-2200322 Proposal 1: Either of following option is taken.

* Option 1: Frequency hopping pattern is determined by physical slot indices for both PUSCH and PUCCH.
  + The length aligned with dl-UL-TransmissionPeriodicity should be supported for the length of hopping interval and configured TDW.
* Option 2: Frequency hopping pattern is determined by physical slot indices for PUSCH and is determined by relative slot indices for PUCCH.
  + The length aligned with dl-UL-TransmissionPeriodicity should be supported for the length of hopping interval and configured TDW.
* Option 3: Frequency hopping pattern is determined by physical slot indices if hopping interval is configured. Frequency hopping pattern is determined by relative slot indices if hopping interval is not configured.

R1-2200337 Proposal 3: Frequency hopping pattern is determined by physical slot indices.

Hopping interval can be implicitly determined by number of repetitions.

Same rules for both PUCCH/PUSCH frequency hopping.

R1-2200382 Proposal 3:

* For inter-slot frequency hopping with inter-slot bundling
  + For PUSCH repetition, frequency hopping pattern is determined based on physical slot index.
  + For PUCCH repetition, frequency hopping pattern is determined based on relative physical slot index.

R1-2200468 Proposal 3: Frequency hopping pattern can be determined by physical slot indices.

R1-2200488 Proposal 1: Frequency hopping pattern for inter-slot frequency hopping with inter-slot bundling is determined by physical slot indices.

R1-2200502 Proposal 1: If a hopping interval is configured, UEs with the hopping pattern should be multiplexed independently from starting slots of PUSCH transmissions of the UEs.

R1-2200591: Proposal 2:

Frequency hopping pattern should be determined by physical slot indices.

R1-2200591: Proposal 3:

The frequency hopping pattern could be different between PUCCH and PUSCH. But the determination rule can be unified to reduce the specification impact and simplify the implementation.

R1-2200614 : Proposal 3: The frequency hopping pattern for inter-slot frequency hopping is determined only by physical slot index.

R1-2200636 Proposal 1: For Rel-17 inter-slot frequency hopping with inter-slot bundling, Rel-15/16 inter-slot frequency hopping pattern design is reused as much as possible.

* + Physical slot index is used for PUSCH.
  + Relative physical slot index is used for PUCCH.

Based on companies’ input, majority support that the frequency hopping pattern for both PUCCH/PUSCH with DMRS bundling is determined by physical slot index, with the following benefits

* Unified solution for PUCCH and PUSCH on TDD, FDD, and SUL
* More friendly to multi-user multiplexing

However, there are also different views. For example, several companies prefer using physical slot index for PUSCH while relative slot index for PUCCH (which seems to follow current Rel-15/16 spec).

Before making a recommend proposal, FL would like to collect more input, especially on what are the technical benefits to adopt different solutions for PUCCH and PUSCH.

**FL question 5: Do you prefer a unified rule/procedure to determine frequency hopping for PUCCH/PUSCH with DMRS bundling. If not, what are the benefits to adopt different rules for PUCCH/PUSCH?**

* **Note: The unified determination rule/procedure still allow to generate different frequency hopping patterns for PUCCH and PUSCH, e.g., different hopping intervals.**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Yes, upon condition. | If a unified rule is agreed, it should be based on relative slot index (first repetition is on slot “0” and so on). This allows to enjoy the largest benefit brough by JCE, especially if the hopping interval duration is a divisor of the cTDW duration, while not sacrificing the frequency diversity. Conversely, we do not see any technical benefit in having a unified solution based on physical slot index. This would be very detrimental for the performance of JCE in most cases.  Some companies state that this would be friendlier to multi-user multiplexing, however this would hardly be the case in practice. Indeed, to enjoy such benefits all UEs would need to be configured with the same hopping interval length. This would impose such hard constraints on NW’s scheduler and limit benefits of JCE so largely then we doubt it would ever been pursued as an objective in an actual deployment. We invite all companies to seriously think about this aspect. More details can be found in R1-2200163. |
| Intel | No. It is not necessary | Our view is that it is more appropriate to extend the existing mechanism as defined in Rel-15, to minimize the spec impact and implementation effort. Following this design principle, for PUSCH, frequency hopping pattern is determined based on physical slot index while for PUCCH, frequency hopping is determined based on relative physical slot index. |
| vivo | YES |  |
| Sharp | Yes | We should strive for common design of inter-slot frequency hopping with DMRS bundling as much as possible. |
| Panasonic | We are open whether to use unified rule/procedure between PUCCH and PUSCH. | To adopt different rules for PUCCH and PUSCH has similar behavior as in Rel.15/16. |
| CATT | Yes |  |
| LG | Yes. | According to the following agreement in RAN1#104-e, unified rule/procedure should be supported to determine frequency hopping for PUCCH/PUSCH with DMRS bundling.  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 |
| WILUS | No | Current specification supports separate rule for PUSCH and PUCCH. Thus, it’s beneficial to reuse current mechanism in terms of specification impact. |
| China Telecom | Yes. | We prefer a unified solution for PUSCH and PUCCH. |
| Samsung | No | Rel-15/16 behavior for the PUCCH allows a uniform FH pattern and better reliability. |
| Ericsson | We think a unified rule is sufficient |  |
| QC | Yes | No need to introduce a difference in the design. Unified design based on physical slot index makes most sense. Maximizing JCE benefits should take a backseat to overall cell efficiency. |
| ZTE | Yes | Unified solution is simper for both UE and gNB implementation. |
| CMCC | Yes. | The window length *L* of the RRC configured TDW is configured separately for PUSCH and PUCCH. From the perspective of flexibility, the configured TDW length of PUSCH and PUCCH can be different. The actual TDW is determined by both configured TDW and frequency hopping interval. As both configured TDW and frequency hopping interval are configured separately, the frequency hopping pattern could be different between PUCCH and PUSCH. Though the frequency hopping pattern could be diverse between PUCCH and PUSCH, the rule for the pattern determination could be unified to reduce the specification impact and simplify the implementation. |
| Lenovo, Motorola Mobility | Yes | Unified design should be aimed for both PUSCH and PUCCH. |
| Xiaomi | Yes | Common design is welcomed for PUSCH and PUCCH. |
| OPPO | Yes | As a basic principle, if possible. |
| Apple | Yes | A unified solution, in terms of how hopping interval is determined, is preferred. See our comment below as well. |

**FL question 6: if a unified rule/procedure is preferred, is the following proposal agreeable?**

* **Proposal: For PUCCH/PUSCH repetitions with DMRS bundling, the inter-slot frequency hopping pattern is determined by physical slot index.**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Not agreeable. | Please see above. |
| Intel | No |  |
| vivo | NO | For inter-slot frequency hopping, the RB index is determined by physical slot index, while it can not be simply reused for frequency hopping per multiple slots. For example, in frame structure DDDDD DDSUU, the frequency hopping interval is 2 slots, and PUCCH/PUSCH is repeated 4 times, i.e., repeated in the last two slots in two consecutive frames. Since the slot index is counted within a frame, the starting RB index for frequency hop in the first frame and the second frame will be the same if the starting RB is determined by the physical slot index. Hence, for inter-slot frequency hopping with DMRS bundling, the starting RB index for each frequency hop can not be determined by slot index. |
| Sharp | We are generally fine with the proposal but suggest to revise as the following:  Proposal: For PUCCH/PUSCH repetitions with DMRS bundling, the inter-slot frequency hopping pattern is determined by **at least** physical slot index. | We agree that multiple UEs with new frequency hopping are multiplexed regardless of starting slot of PUSCH/PUCCH repetitions for each UE.  However, in terms of the number of slots in a radio frame, the new frequency hopping pattern should be determined by physical slot index and SFN. For example, the number of slots in a radio frame when = 0 is only 10 slots even if the number of repetitions is more than 10 slots. |
| Panasonic | Agreeable if the length aligned with *dl-UL-TransmisisonPeriodicity* is supported. | If hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. |
| CATT | Yes | The question raised by vivo can be easily tackled by using frame number to distinguish the slots in different frames. |
| LG | Yes. |  |
| NTT DOCOMO | Yes, upon condition | We have concern for the DMRS bundling performance, e.g TDD pattern is DDSUU and configured TDW length = hopping interval =2, frequency hops with DD SU UD DS UU… so that we lose DMRS bundling at the first PUCCH/PUSCH transmission. On the other hands, if we can assume sufficient number for TDW length = hopping interval (e.g. = *dl-UL-TransmisisonPeriodicity*, 5 in this example), our concern is cleared and we see the comment from Panasonic that the hopping pattern can be the same. |
| China Telecom |  | First, we think we need to make some clarification. In our view, there are 2 issues for hopping pattern design:  1. The start of hopping pattern is based on absolute slot index or relative slot index?  2. Counting of hopping interval is based on available slot or physical slot?  For the 1st one, we think the start of hopping pattern for paired spectrum and unpaired spectrum is different, i.e. for unpaired spectrum, the start of hopping pattern is based on absolute slot index; for paired spectrum, the start of hopping pattern is based on relative slot index.  For the 2nd one, we prefer that the counting of hopping intervals is based on physical slots for both PUSCH and PUCCH, regardless of counting method. |
| Samsung | No | See input to previous question. For PUCCH, a relative slot index should be used, as in Rel-15/16. |
| Ericsson | OK in principle, but we prefer to not limit Rel-17 PUCCH/PUSCH to depend on DMRS bundling being configured. Suggest:  **Proposal: For PUCCH/PUSCH repetitions ~~with DMRS bundling~~, the Rel-17 inter-slot frequency hopping pattern is determined by physical slot index.** | As LGE point out in R1-2200614, for Rel-15/16 PUCCH, startingPRB is applied if the slot index is even, and secondHopPRB is applied if the slot index is odd, so for both PUCCH and PUSCH physical slots are used to determine the hopping pattern. |
| QC | Yes | This is the best option from a cell efficiency perspective. |
| ZTE | No | We prefer that inter-slot FH pattern could be determined by relative physical slot index. If based on physical slot index, the start of a hopping pattern may not be aligned with the start of a configured TDW. This would cause too segmented TDWs and then degrade the performance.  In addition, if this is based on physical slot index, we would like to clarify whether the legacy condition that FH would be cycled in even radio frame should be kept or not. |
| CMCC | Yes. | The legacy mechanism uses the parity of the physical slot to indicate how the UE perform UL transmission with FH. From our point of view, using physical slot makes it easier to match with the TDD slot duration.  The starting of the FH pattern can align with the starting of the DMRS bundling by adding a offset. |
| Lenovo, Motorola Mobility | Yes |  |
| Spreadtrum | Yes |  |
| Xiaomi | Yes |  |
| OPPO | Yes |  |
| FL | @Panasonic @ DCM, the hopping interval is likely to be agreed by RRC configuration. Then gNB can configure hopping internal aligned with dl-UL-TransmisisonPeriodicity. So I think your concern can be addressed by gNB implementation. | |
| Apple | No. See comments | The hopping interval can start relative to the first repetition occasion (no need to have a fix hopping pattern which is determined by physical slot index). For example, the first 4 repetitions, starting from the first repetition, are on the first hop, the next 4 repetition “occasions” are on the second hop, and so on. Now if some (or even all) occasions in a hop interval are dropped, the pattern is fixed (and not floating). This is similar to R15/16 procedure, where the first repetition is always on the first hop and every other repetition on the other hop (and first and second hop are not fixed based on physical slot index, but they are relative to the starting repetition), and the pattern is fixed no matter which occasions are usable or not. So Rel-17 follows the same and simply introduces hopping interval (e.g. 4 slots instead of 1 slot in R15/16). |
| Huawei, HiSilicon |  | @Ericsson, regarding your proposal, we feel the proposal could be revised to be about only PUCCH repetition since no change to PUSCH repetition. However, could you please clarify a bit what UE capability you expect for it? All Rel-17 UEs support it mandatorily or optionally? If optionally, the situation has no change in Rel-17 where a gNB has to coordinate two kinds of UEs anyway in multiplexing FH resources. So the resource management is still not unique. What potential gains could be in your view? |

**FL question 7: If separate rules/procedures to determine frequency hopping for PUCCH/PUSCH with DMRS bundling are preferred, is the following proposal agreeable?**

* **Proposal: For inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling**
  + **For PUSCH repetitions, frequency hopping pattern is determined based on physical slot index.**
  + **For PUCCH repetitions, frequency hopping pattern is determined based on relative physical slot index**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Acceptable as a middle ground. | This is not our first preference |
| Intel | Support | Same comment as above. |
| vivo | No | As we commented for FL question 6, FH pattern based on physical slot index may result in NO FH, when the repetitions cross the frame boundary.  The same rule can be applied for PUCCH and PUSCH repetitions. |
| Panasonic | Agreeable if the length aligned with *dl-UL-TransmisisonPeriodicity* is supported. | If hopping interval and configured TDW length are the same as the period of TDD {DL+S+UL} slots, hopping pattern can be same regardless of hopping pattern is determined by physical slot or relative slot indices. |
| CATT | OK |  |
| NTT DOCOMO | Yes, upon condition | Same comment as above. |
| WILUS | Yes | Same comment as FL question 5. |
| Samsung | Yes |  |
| Ericsson | Not agreeable at this stage | There seems to be confusion in RAN1 on the differences between PUCCH and PUSCH frequency hopping as we comment for FL proposal 6. We can revisit this if needed after clarifying the intended differences between physical and relative physical slot indices. |
| QC | No, needs justification | RBs assigned for PUCCH will go unused. Not a good design from a cell resource utilization perspective. |
| ZTE | No | Unified solution is simper for both UE and gNB implementation. |
| Spreadtrum | Yes |  |
| Apple | No | Separate procedure not needed |

### FFS: details of FH pattern design

R1-2200054 Proposal 2: Further enhancement of frequency hopping pattern is not necessary.

R1-2200089 Proposal 5: For frequency hopping with DMRS bundling, the starting RB is determined by the interval index

* The first hopping interval starts from the first PUSCH/PUCCH repetition, and has a number of slots according to configured interval length or configured TDW length.
* New frequency hopping interval is created if there are remaining repetitions not covered by previous intervals.

R1-2200114 Proposal 2: For PUSCH/PUCCH repetition, frequency hopping pattern is determined by the legacy rules for inter-slot frequency hopping for PUCCH repetition defined in Rel-15/16.

* The UE performs frequency hopping per frequency hopping interval.
* The frequency hopping interval indicated to the UE containing the first PUSCH/PUCCH transmission has number 0 and each subsequent frequency hopping interval until the UE transmits all PUSCH/PUCCH repetitions is counted regardless of whether or not the UE transmits the PUSCH/PUCCH in the frequency hopping interval.

R1-2200163 Proposal 2. Define frequency hopping interval in case of DM-RS bundling constrained to being either equal to the length of the configured TDW or a divisor of the length of the configured TDW.

R1-2200208 Proposal 2:

For DMRS bundling for PUCCH transmission with repetitions, the frequency hopping interval can be larger than one slot.

R1-2200208 Proposal 3:

For DMRS bundling for PUCCH transmission with repetitions, further discuss whether the number of hops is larger than two.

R1-2200280 Proposal 5: For the inter-slot frequency hopping with DMRS bundling for PUSCH/PUCCH:

* + Hopping offsets are determined by the physical slot index and frequency hopping interval

R1-2200322 Proposal 2: Frequency hopping pattern based on physical slot indices is realized as following.

* The starting RB during slot is given by
  + - is the current slot number within a radio frame
    - is the starting RB within the UL BWP as calculated from the resource block assignment information
    - is the frequency offset in RBs between the two frequency hops
    - is the length of hopping interval

R1-2200322 Proposal 3: Frequency hopping pattern based on relative slot indices is realized as following.

* The starting RB during slot is given by
  + - is the relative slot number. The slot indicated to the UE for the first PUSCH/PUCCH repetition has number 0 and each subsequent slot until the UE transmits the PUSCH/PUCCH in slots is counted regardless of whether or not the UE transmits the PUSCH/PUCCH in the slot.

R1-2200502 Proposal 2: If a hopping interval is configured, the hopping pattern should be determined as:

R1-2200614 Proposal 6: The bundle size can be same as or different from the time domain window size.

R1-2200636 Proposal 2: Following methods can be further considered to maximize the gain of joint channel estimation in case of both hopping interval (i.e., L’) and configured TDW length (i.e., L) are configured:

* + Alt 1: A UE does not expect to be configured as hopping interval (i.e., L’) > configured TDW length (i.e., L).
  + Alt 2: Hopping interval (i.e., L’) is used for determination of configured TDW length if configured hopping interval value of L’ is larger than configured TDW length value of L.

R1-2200658 Proposal 2:

* Enhanced frequency hopping designs for PUCCH and PUSCH include the following:
  + Frequency hopping offsets are determined from a hopping index that is calculated from the (physical) slot number, where the hopping index changes once every N slots, the index can attain up to M values, and the hopping pattern has a configurable time shift (in the unit of slots).
    - Increased hopping offsets over Rel-15 are supported, e.g. M=4,
  + UE capability for support for the Rel-17 frequency hopping pattern is independent from that of joint channel estimation

There are three major open issues regarding the details of the FH pattern design.

* Issue 1: How to decide frequency hopping interval, i.e., derived by other parameters such as configured TDW or explicated configured by a new RRC parameter(e.g., R1-2200153 Proposal 3)?
* Issue 2: Whether increase the number of frequency offset over Rel-15/16 are supported?
* Issue 3: What is the exact equation to decide hopping pattern?

For issue 3, the solution depends on the decision for questions in Section 3.2.1. FL suggest to put the discussion on issue 3 on hold until the open issues in Section 3.2.1 are resolved. For issue 1 and 2, FL would like to collect companies’ answers to the following two questions as below.

**FL question 8: The hopping intervals for PUCCH/PUSCH repetitions with DMRS bundling should be derived based on parameters or configured by new RRC parameters?**

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Nokia/NSB | In our view existing agreements stipulate that hopping intervals for PUCCH/PUSCH should be configured, and a fallback mechanism should exist in case they are not configured. We are not sure that having a mechanism exclusively based on a derivation of the FH interval duration respects existing agreements. Having said this, we also think that existing agreements allow a derivation based on a new RRC parameter, e.g., such new RRC parameter could be the ratio between FH interval and TDW duration, to ensure that an integer number of complete FH intervals is present in each TDW and that performance of JCE is maximized. |
| Intel | According to the agreement from last meeting, a new RRC parameter is needed:   * Support separate RRC configuration(s) for hopping interval and configured TDW length |
| vivo | It seems already discussed in last meeting, if hopping interval is configured, it is a new parameter by nature. If hopping interval is not configured it is derived from the configured TDW |
| Sharp | Hopping interval should be configured by new RRC parameters. |
| Panasonic | Hopping intervals should be derived based on *Frequencyhopping-Interval* in Section 2.2 and/or configured TDW length. |
| CATT | To FL’s Question 8, using an explicit RRC parameter to configure hopping interval is clear and preferred. Additionally, default value may be determined (e.g. in Section 4.2.3) if the explicit RRC parameter is absent.  To clarify, ‘how to inform the UE to perform inter-bundling hopping’ seems to be one missing piece for this feature… Our suggestion (R1-2200153 Proposal 3) is by explicit RRC configuration, e.g. to add ‘*interBundling*’ in ‘*frequencyHopping’* IE in *PUSCH-Config* for PUSCH. For PUCCH, it depends on whether it is per BWP configured or per format configured. |
| LG | To align with the default value for the hopping interval, which is same with the configured TDW length, it should be derived based on parameters, especially configured TDW length. |
| WILUS | Based on agreements, it’s clear to introduce new RRC parameter, which denotes the value of hopping interval. Other RRC parameter is not necessary. |
| China Telecom | In our views, the hopping intervals should be configured by new RRC parameter. |
| Samsung | The hopping intervals can be derived without dedicated RRC configuration – there is no need to have new RRC parameters for such purpose. |
| Ericsson | We agreed to have separate RRC configurations for hopping interval and configured TDW length, and so hopping intervals are at least defined independently of TDW length. As such, new parameter(s) are already needed for Rel-17 inter-slot hopping. |
| QC | Hopping intervals must be set to be the same value for UEs across a cell to ensure resources are used efficiently. They should be independently set by the gNB. An RRC parameter for this purpose will be good to have. |
| ZTE | As discussed in section 2.2., FH intervals can be configured by new RRC, and if not configured, the default hopping interval is the same as the configured TDW length. This also aligns with previous agreements. |
| Lenovo, Motorola Mobility | Hopping intervals should be derived based on Frequencyhopping-Interval and configured TDW length. |
| Spreadtrum | Hopping interval should be determined via new parameter. |
| Xiaomi | Hopping interval should be determined via new RRC parameters. |
| OPPO | We prefer to derived from existing parameter. |
| Apple | Please see our comment to FL P.6 |

**FL question 9: For frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling, should Rel-17 increase the number of frequency offset over what are supported in Rel-15/16?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | No need. |  |
| Intel | No | Increasing the number of frequency offsets for inter-slot frequency hopping is out of the scope for PUSCH/PUCCH coverage enhancement. |
| vivo | No |  |
| Sharp | No need |  |
| Panasonic | No. | Although we understand it improve the performance, we think it is rather optimization given the end of WI. |
| CATT | We do not see strong need. |  |
| LG | No | We do not think have enough time to introduce something new considering all we have for frequency hopping of DMRS bundling now is sequential ordering of TDW and hopping interval. It should be deprioritized or at least revisit after offset determination, hopping pattern and configuration is settled. |
| NTT DOCOMO | NO |  |
| WILUS | No | It was discussed during SI phase as frequency domain enhancement and concluded not to support in Rel-17 CovEnh WI. |
| China Telecom | No | There seems not enough time for this. |
| Samsung | No | Considering that 1 hop and 4 Rx antennas already provide a diversity order of 8, which is more than enough (without even considering any time diversity due to repetitions), we see no need for increasing the number of frequency offsets. |
| Ericsson | Yes. | As we show in R1-2200657, there are gains (e.g. 0.5 dB @ 10% BLER and 1.5 dB @ 1% BLER) from new hopping patterns with an increased number of frequency hopping offsets when used both with and without DMRS bundling. We also find similar gains for increased hopping offsets with TBoMS and with PUCCH. Therefore, we suggest to support Rel-17 frequency hopping patterns that can be configured independently of DMRS bundling, for PUSCH and PUCCH transmission. Such hopping should be supported for TBoMS.  Overall, we think these gains are quite low hanging fruit, and a new pattern with additional offsets should be relatively straightforward. We hate to leave such gains on the table for TDD. |
| QC | No | This is out of scope. |
| ZTE | No |  |
| CMCC | No. |  |
| Lenovo, Motorola Mobility | No |  |
| Spreadtrum | No |  |
| Xiaomi | No |  |
| OPPO | Yes | We can consider up to 4. As this will be useful for longer repetition. |
| Ericsson2 | Yes | We would hope the majority can give this a little more thought.  If the concern is scope of the WI, then it is worth pointing out that the WI only calls for enhancing inter-slot hopping for PUSCH (see excerpt below). Given the general support for PUCCH frequency hopping enhancements, companies seem to be open to enhancing frequency hopping beyond what is strictly in the WID.   * Specification of PUSCH enhancements [RAN1, RAN4]   …   * + - Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]   If the concern is that increasing the number of frequency hopping offsets would lead to a complicated frequency hopping pattern, we think one way to specify the pattern is with something like the following.  hopping\_offset = floor((slot\_num+offset)/hop\_duration) mod num\_hops  If the concern is that there is limited gain, we would hope companies have simulated this and can share their findings. Our results can be found in R1-2200657 (PUSCH Rep. Type A), R1-2200658 (PUCCH), and R1-2200660. Again, we find useful gains (e.g. 0.5 dB @ 10% BLER and 1.5 dB @ 1% BLER) from new hopping patterns with an increased number of frequency hopping offsets when used both with and without DMRS bundling, and have similar observations for PUSCH Rep Type A, TBoMS, and PUCCH. |
| Apple | No |  |
| Huawei, HiSilicon | No for PUCCH | We don’t feel there are sufficient potential gain for PUCCH because PUCCH resources are typically configured at the edge of a carrier bandwidth in order to avoid frequency resource fragmentation of PUSCH (considering PRB contiguity required by DFT-s-OFDM waveform for UL coverage). It means very limited FH distance could be introduced by the third FH offset, resulting in very limited gain.  In R1-2200658, the negative impact on PUSCH has not been analyzed. |

### FFS: if both hopping interval and TDW length are not configured

R1-2200114 Proposal 3: If both hopping interval and configured TDW are not configured, the default hopping interval is equal to half of the duration of all PUSCH/PUCCH repetitions.

R1-2200153 Proposal 1: The default hopping interval is equal to the default window length of the configured TDW, i.e. the minimum of maximum duration and the duration of all PUSCH/PUCCH transmissions, if neither of hopping interval or configured TDW length is configured.

R1-2200163 Proposal 3. Set the frequency hopping interval length equal to the configured TDW length, in the case the configured TDW length is not configured, and the frequency hopping interval is not configured

R1-2200239 Proposal 2: If both hopping interval and TDW length are not configured, default value for configured TDW length (= hopping interval) is used.

R1-2200280 Proposal 1: When both hopping interval and TDW length are not configured, down select between:

* Half of default configured TDW length can be used as frequency hopping interval, which is 1/2\*min (maximum duration, duration of all PUSCH repetitions).
* Not allowed this case.

R1-2200322 Proposal 4: If both hopping interval and TDW length are not configured,

* If DMRS-budling is enabled, default hopping interval should be same as the default TDW length.
* If DMRS-budling is not enabled, Rel.15/16 hopping pattern should be applied.

R1-2200468 Proposal 4: If both hopping interval and TDW length L are not configured, the first step is to determine the default value of L = min (maximum duration, duration of all PUSCH repetitions), then the hopping interval can be the same as the default TDW length L.

R1-2200502 Proposal 6: When hopping interval and window length L are not configured, a half of the configured TDW should be equal to the default hopping interval to achieve both frequency hopping gain and DMRS bundling gain.

R1-2200521 Proposal 1: If both hopping interval and TDW length are not configured, hopping interval is determined by L = min (maximum duration, duration of all PUSCH repetitions) and L = min (maximum duration, duration of all PUCCH repetitions) for PUSCH and PUCCH, respectively.

R1-2200614 Proposal 5: In case the joint channel estimation is enabled and frequency hopping is indicated without a hopping interval and configured TDW, the default value for configured TDW should be applied as a default value for the hopping interval.

R1-2200636 Proposal 3: If both hopping interval (i.e., L’) and configured TDW length (i.e., L) are not configured, hopping interval is determined as a single slot, i.e., Rel-15/16 inter-slot frequency hopping can be reused.

Based on the input from companies, there are four options to solve this issue of default hopping interval, if both hopping interval and TDW length are not configured.

* **Option 1: half duration of PUCCH/PUSCH repetitions**
  + **Supporting companies: Intel, Samsung, ZTE, OPPO**
* **Option 2: default window length of the configured TDW**
  + **Supporting companies: Nokia/NSB, VIVO, CATT, Panasonic (conditioning on DMRS bundling enabled), LG, DCM, IDC, CT, Ericsson, CMCC, Lenovo/Moto, Spreadtrum, Xiaomi, HW/HiSi**
* **Option 3: half of default window length of the configured TDW**
  + **Supporting companies: Intel, Sharp, ZTE**
* **Option 4: a single slot (fallback to Rel-15/16 inter-slot frequency hopping)**
  + **Supporting companies: Panasonic (conditioning on DMRS bundling is disabled), WILUS, QC**

FL would like to collect more input on this topic, especially the pros and cons for each option.

**FL question 10: Which one of the above 4 option you prefer, and why?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Option 2. | Existing agreement stipulates that if hopping interval is not configured, the default hopping interval is the same as the configured TDW length. Given that we also have a default TDW length if the latter is not configured, the most straightforward behavior is to set the default FH internal length equal to the default TDW length. Any other decision seems rather arbitrary to us, with no solid justification. |
| Intel | We are fine with Option 1 or 3 | For the case when configured TDW is equal to the number of repetitions and if default bundling size for inter-slot frequency hopping is equal to the number of repetitions or configured TDW size, this would indicate that inter-slot frequency hopping with inter-slot bundling is not enabled. Using half of the configured TDW or the number of repetitions would enable inter-slot frequency hopping with inter-slot bundling |
| vivo | Option 2 | It has been agreed that the default frequency hopping interval is the configured TDW length. Furthermore, based on agreements in AI 8.8.1.3, if TDW length is not configured, the default TDW length is min (maximum duration, duration of all PUSCH/PUCCH repetitions). Hence, when neither hopping interval nor TDW length is configured, the frequency hopping interval is min (maximum duration, duration of all PUSCH/PUCCH repetitions) |
| Sharp | Option 3 | At least, the UE should achieve frequency diversity for PUSCH/PUCCH with frequency hopping. |
| Panasonic | Option 2 if DMRS-budling is enabled.  Option 4 if DMRS-budling is not enabled |  |
| CATT | Option 2 | This is a straight forward option. No need to make this issue too complicated.  If a specific value is needed, the gNB shall configure the hopping interval explicitly. |
| LG | Prefer option 2. | It is quite clear to us by combining two default behaviors, i.e., “if hopping interval is not configured, the default hopping interval is the same as the configured TDW length” and “if L is not configured, the default value of L = min (maximum duration, duration of all PUSCH repetitions)”. We are running out of time and still have things to wrap up, it will be the simplest solution without spec impact. |
| NTT DOCOMO | Option 2 |  |
| InterDigital | Option 2 | Setting the hopping interval equal to the default TDW length offers consistent operation. |
| WILUS | Option 4. | Default UE behavior should be Rel-15/16 inter-slot frequency hopping since UE is configured *interslotFrequencyHopping* in *PUCCH-FormatConfig* as enabled.  In this case, frequency hopping can be performed regardless of joint channel estimation. |
| China Telecom | Option 2. | It has been agreed to support separate RRC configuration(s) for hopping interval and configured TDW length and if hopping interval is not configured, the default hopping interval is the same as the configured TDW length. In our understanding, if both hopping interval and TDW length are not configured, the default value of frequency hopping if clear, i.e., equal to the default value of *PUSCH-TimeDomainWindowLength*. |
| Samsung | Option 1 | Default FH interval should be half the number of repetitions. No need for more complex solutions and none of the other options can result to better performance. |
| Ericsson | Option 2 | Our understanding is that this is the case where Rel-17 inter-slot hopping is configured, but without a hopping interval provided, since configuring Rel-15/16 hopping should be always be possible.  Then with this understanding, Option 2 is consistent with existing agreements, since if the interval is not configured, the default hopping interval is the same as the configured TDW length, and there is a default TDW length already agreed (=min{maximum duration, duration of all PUSCH repetitions}). |
| QC | Option 4 | All other options are dependent on UE specific parameters and are therefore invalid. |
| ZTE | Prefer Option 1 and also ok with Option 3 | For Option 2, if the default TDW length equals to the duration of all PUSCH repetitions, the gain from frequency hopping is lost.  Option 4 would lost the DMRS bundling gain. |
| CMCC | Option 2 | Considering that we have agreed the default frequency hopping interval is the length of configured TDW, and the TDW length also have a default value if it is not configured, we proposed to support the option 2. |
| Lenovo, Motorola Mobility | Option 2 |  |
| Spreadtrum | Option 2 | The default TDW length equals to min (maximum duration, duration of all PUSCH repetitions). |
| Xiaomi | Option 2 | The default TDW length equals to min (maximum duration, duration of all PUSCH repetitions). |
| OPPO | Option 1 |  |
| Huawei, HiSilicon | Option 2 | Simple and consistent solution. |

### Second round discussion

Companies feedback in previous round are summarized as below.

**Support a unified rule/procedure to determine frequency hopping for PUCCH/PUSCH with DMRS bundling**

* **VIVO, Sharp, CATT, LG, CT, Ericsson, QC, ZTE, CMCC, Lenovo/Moto, Xiaomi, OPPO, Panasonic(?), Nokia/NSB (conditioning on unified solution based on relative physical slot index)**

**Support separate rules/procedures to determine frequency hopping for PUCCH/PUSCH with DMRS bundling**

* **Intel, WILUS, Samsung, Nokia/NSB**

For detailed hopping pattern design, the views are very diverged, as summarized below.

**Option 1: Physical slot index is used to determine frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.**

* **Supported by: Sharp, CATT, LG, Ericsson, QC, CMCC, Lenovo/Moto, Spreadtrum, Xiaomi, OPPO, Panasonic(?), DCM(?)**

**Option 2: Relative slot index is used to determine frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.**

* **Supported by: Nokia/NSB, ZTE**

**Option 3: Interval index is used to determine frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.**

* **Supported by: VIVO**

**Option 4: Physical slot index is used to determine frequency hopping for PUSCH repetitions with DMRS bundling. Relative slot index is used to determine frequency hopping for PUCCH repetitions with DMRS bundling.**

* **Supported by: Intel, Samsung, WILUS, CATT, Spreadtrum, DCM (?), Panasonic(?)**

**Option 5:**

**Starting of the PUCCH/PUSCH hopping pattern is based on**

* **physical slot index for unpaired spectrum**
* **relative slot index for paired spectrum**

**Counting of the hopping intervals is based on physical slot index for PUCCH/PUSCH hopping pattern**

* **Supported by: CT**

Apparently, RAN1 cannot move forward with too many options on the table. Based on the feedback received so far, FL recommend to focus on option 1 and option 4 and further discuss them.

**FL proposal 3a: For inter-slot frequency hopping for PUCCH/PUSCH with DMRS bundling, down-select (in RAN1#107bis-e) between the following two options**

* **Option 1: Physical slot index is used to determine inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.**
* **Option 4: Physical slot index is used to determine inter-slot frequency hopping for PUSCH repetitions with DMRS bundling. Relative slot index is used to determine inter-slot frequency hopping for PUCCH repetitions with DMRS bundling.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CATT | Fine with the proposal. |
| Nokia/NSB | @FL: While we understand that what you are doing is a sensible course of action given the preferences expressed so far, we have the feeling that there is a surprising disagreement across companies on how legacy FH framework works for PUCCH (please see below). We are taking a very important decision here, and we feel that some companies may be looking at the problem from a very unusual perspective. Therefore, **would it be possible to have a quick check on this across companies? This is rather fundamental in our view.**  @Ericsson, @LGE: we are surprised to read that according to your understanding both PUCCH and PUSCH determine the starting PRB and second Hope PRB based on physical slot index. TS 38.213 does not state this for PUCCH, as per excerpt below (please check highlighted part). Our understanding is that relative slot index is used in legacy operations for PUCCH. We must be very careful with any decision we take in this regard if our understanding is not aligned.  Clause 9.2.6: “the UE transmits the PUCCH starting from a first PRB, provided by startingPRB, in slots with even number and starting from the second PRB, provided by secondHopPRB, in slots with odd number. The slot indicated to the UE for the first PUCCH transmission has number 0 and each subsequent slot until the UE transmits the PUCCH in slots is counted regardless of whether or not the UE transmits the PUCCH in the slot”  At this stage, it is also worth adding that this legacy behavior for PUCCH is very reasonable in our view, given that very few PRBs are used for PUCCH transmission, hence any possible “spectral inefficiency” due to relative slot index utilization (which has never been demonstrated, anyway…) would not happen in practice. It should then be noted that PUSCH/PUCCH transmissions from UEs in coverage shortage scenarios, and for which DM-RS bundling is required, are expected to be scheduled in the same exact way, i.e., with PUSCH/PUCCH transmissions spanning only few RBs to maximize the power spectral density per RE (EPRE). This is a fundamental consideration when thinking that even if gNB needs to reserve both *startingPRB* and *secondHopPRB* for a specific UE, it does not implicate large inefficiencies in spectral allocation, even in the worst case. |
| China Telecom | We think one more thing is needed to be clarified, does “physical slot index is used to determine inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling” also contains the meaning of “counting of the hopping intervals is based on physical slot regardless of PUSCH/PUCCH counting method (based on available slot or physical slot)”?  Different from legacy PUCCH/PUSCH inter-slot frequency hopping, where the duration for each hop is a single slot. For inter-slot frequency hopping with DMRS bundling, the unit of duration for each hop also needs to be considered. Thus, we think the above clarification is needed. |
| vivo | Fine with this proposal. And prefer opt-4 since frequency hopping is determined by relative slot index for PUCCH, as clarified by Nokia. And agree with the clarification from CTC. |
| Intel | We are fine with the proposal.  We share similar view as Nokia that as defined in Rel-15/16, inter-slot frequency hopping for PUCCH repetition is based on relative physical slot index. But we do not follow the motivation of introducing relative physical slot index for inter-slot frequency hopping due to small number of PRBs. Our view is that using physical slot index would achieve similar goals as using relative physical slot index, which is fully under the control by the network.  For the comment from CTC, our view is that this is based on physical slot index/relative physical slot index regardless of whether the counting is based on available slot or physical slot. This is aligned with the existing behavior for inter-slot frequency hopping without inter-slot bundling. |
| Nokia/NSB2 | @Intel: it is argued by some companies that using physical slot index provides better spectral efficiency as oppose to relative slot index. What we meant with our comment is even if this was true, the effect would be negligible for the use case we are considering. Indeed, both PUCCH and coverage-limited PUSCH would always be configured with very low number of PRBs. In this sense, there would be no noticeable difference between using physical or relative slot index from spectral efficiency point of view, as you say. We have similar views. Using relative slot index allows, instead, to ensure that the first slot of the first hop is always the first slot of the TDW. This is very convenient for maximizing the performance of JCE.  @CTC: frequency hopping interval determination should be independent on the counting method, according to our understanding. |
| QC | @Nokia, are you telling the operators that their spectrum is not valuable enough and that what could have been accomplished with X RBs of spectrum now requires 2X RBs? Its not a matter of a few RBs as every UE now configured with inter slot frequency hopping will require 2X the resources.  If we enable inter-slot frequency hopping, we need to have a clear plan on how we are going to use the complementary resources (unused resources from the other hop). If we don’t, its probably best to not have this feature. We think efficient use of the complementary resources are the central question here.  R15 design need not be the gold standard. We should strive to constantly improve the spec and not be too beholden to legacy operation. What is the point of having new releases otherwise? |
| Ericsson | We can support FL proposal 3a.  @Nokia: I stand corrected regarding ‘relative slot index’ for PUCCH. Thanks for the discussion.  Regarding spectral efficiency, we think it is a consideration, noting that PUCCH repetition by its nature is spectrally inefficient. One could make the argument that SRS capacity is not an issue, since SRS uses very little resources, but we have continually enhanced its capacity over releases, e.g. with A-SRS, higher comb density, etc. |
| Samsung | Option 4. No need to change Rel-16 when no better solution is proposed. |
| Panasonic | We are fine with the proposal as long as the value range of the hopping interval in Section 2.2 is supported. |
| Sharp | We are fine with the proposal if Option 1 doesn’t intend to “only” use physical slot index. |
| NTT DOCOMO | We are fine with the proposal, and see the comment form FL in the 1st round discussion. We think the hopping interval is appropriately configured (e.g. 5 for DDDUU TDD pattern), Option 1 and 4 have the same hopping pattern. In that case, we prefer Option 4 with taking the current rule. |
| WILUS | We support the FL proposal 3a and prefer Option 4. More specification effort is necessary if physical slot index is used to determine inter-slot FH pattern for PUCCH repetitions that is quite different with Rel-15/16 inter-slot FH pattern for PUCCH repetitions. |
| OPPO | The 2 options are fine for the moment. We prefer Option1 as the Hopping pattern would be varying very much different if we use logic slot only for PUCCH. Considering different case UEs have support, e.g. HD-FDD. |
| ZTE | Option 1 seems to prioritize the multiplexing efficiency over the performance. As commented before, if based on physical slot index, the start of a hopping pattern may not be aligned with the start of a configured TDW. This would cause too segmented TDWs and then degrade the performance. In our view, ensuring the performance by using relative physical slot index is more reasonable for both PUCCH and PUSCH in coverage limited scenario.  Regarding the multiplexing efficiency, we share with Nokia that the advantage from Option 1 could be negligible. Because legacy UEs or new UEs in cell center would still use relative slot scheduling for PUCCH transmission, gNB anyway needs to consider how to multiplexing them together efficiently. For instance, gNB could always schedule PUSCH/PUCCH without repetition for cell center UEs to fill up the RB holes if any, similar as legacy operation. |
| FL | @CTC, I am not sure what you meant by: “counting of the hopping intervals is based on physical slot regardless of PUSCH/PUCCH counting method (based on available slot or physical slot)”? In my understanding, the following are the equations corresponding to using physical or relative slot index to decide the starting RB index. As you can see, the only difference is the input to the equation is physical slot index or relative index. Suppose we down select to use physical slot index, then we just need to run the equation for each physical slot which will tell us the start RB for each physical slot. With that, everything is determined including the hopping interval. I am not sure what is the extra step to count hopping internal. The same applies to relative slot index. You run the equation for each relative slot. The equation will tell you the starting RB for that relative slot. Once the starting RB for each relative slot is decided, the hopping interval is automatically decided. Again, I don’t see a extra step of counting is needed.  R1-2200322 Proposal 2: Frequency hopping pattern based on physical slot indices is realized as following.   * The starting RB during slot is given by   + - is the current slot number within a radio frame     - is the starting RB within the UL BWP as calculated from the resource block assignment information     - is the frequency offset in RBs between the two frequency hops     - is the length of hopping interval   R1-2200322 Proposal 3: Frequency hopping pattern based on relative slot indices is realized as following.   * The starting RB during slot is given by   + - is the relative slot number. The slot indicated to the UE for the first PUSCH/PUCCH repetition has number 0 and each subsequent slot until the UE transmits the PUSCH/PUCCH in slots is counted regardless of whether or not the UE transmits the PUSCH/PUCCH in the slot. |
| Lenovo, Motorola Mobility | Support the proposal and prefer option 4 |
| LG | Fine for the downselection between options. @Nokia: Thanks for the clarification. We are aware of legacy behavior, but for multi UE multiplexing, we think it should be option 1. We think whether spectral efficiency is achieved or not is left for NW implementation but more important thing is making room for it. |

For the issue of determining default hopping interval in case of both hopping interval and TDW length are not configured, based on the feedback collected, FL recommend take option 2.

**FL proposal 3b: In case of both hopping interval and TDW length are not configured, the default hopping interval is the default window length of the configured TDW.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| CATT | Fine with the proposal. |
| Nokia/NSB | Support |
| China Telecom | Support. |
| Vivo | Support |
| Intel | We do not support this proposal. If we agree with the proposal, this means that inter-slot frequency hopping with inter-slot bundling is disabled.  Using half of the configured TDW or the number of repetitions would enable inter-slot frequency hopping with inter-slot bundling |
| Ericsson | Support. We are not sure how hopping is constrained since there are independent parameters for the interval and the TDW, allowing full network control. |
| Samsung | We don’t support the proposal. If there is no configuration of frequency hopping interval (configuration of frequency hopping interval is not agreed) and configuration of TDW length, the default should be half of the number of repetitions. Besides, FH interval equal to number of repetitions is equivalent to no frequency hopping, which should not be the case as the above configurations should not be mandated in order to have FH. |
| QC | Do companies mean half the maximum duration reported by the UE? |
| Panasonic | Support |
| NTT DOCOMO | We are with the proposal. |
| WILUS | We still wonder why default hopping interval is the default value of L even *interslotFrequencyHopping* is configured as enable. Fallback to legacy inter-slot FH is backward compatible. Compromisingly, it seems reasonable though to add conditions what Panasonic have proposed. In other words, different default hopping intervals can be supported depending on whether DMRS bundling is enabled or not. |
| OPPO | If the 2 are not configured, should simply not hopping. Or fallback to Rel-16 repetition. Optimization should be avoided. |
| ZTE | We do not support the proposal. The proposal would mean enabling/disabling FH may reply on the configuration of TDW, which is not reasonable for us. We should ensure FH for better performance if possible, instead of disabling it. |
| Lenovo, Motorola Mobility | Support the proposal |
| LG | Support. |
| Huawei, HiSilicon | OK. |

## Frequency hopping for TBoMS

There are a few proposals to support frequency hopping for TBoMS, which are listed as below.

R1-2200519 Proposal 3:

* In case of DMRS bundling, inter-slot frequency hopping with inter-slot bundling is supported for TBoMS.
  + Frequency hopping pattern for TBoMS is determined based on physical slot index.
* For repetition of a single TBoMS transmission, inter-repetition frequency hopping is supported.

R1-2200152 Proposal 4: Inter-slot frequency hopping with inter-slot bundling is supported for TBoMS at least for the case when DMRS bundling is applied.

R1-2200466 Proposal 3: Support intra-TB frequency hopping for TB processing over multi-slot PUSCH.

R1-2200604 Proposal 8: The bundling of inter-slot frequency hopping should be supported for TBoMS.

As these are new proposals submitted in this meeting, FL would like to collect feedback on these proposals before making a recommendation.

**FL question 11: Should inter-slot frequency hopping with DMRS bundling supported for TBoMS, and why?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Answer** | **Comment** |
| Nokia/NSB | Yes | In our view, there does not seem to be any agreed restriction on the application of JCE to TBoMS. Therefore, we do not see why inter-slot frequency hopping with DMRS bundling should not be supported for TBoMS. However, this should come with no specific optimization targeting TBoMS. |
| Intel | Yes | Share similar view as Nokia. |
| Vivo | YES | The same mechanism for inter-slot FH with DMRS bundling for type-A PUSCH repetition can be reused for TBoMS. New mechanisms should be avoided. |
| Sharp | Yes |  |
| Panasonic | Yes | The same mechanism as PUSCH repetition Type A should be supported. |
| CATT | Yes | Combination of TBoMS, DMRS bundling and inter-bundling hopping can extend the coverage as much as possible. This seems not a big issue since the TDRA of TBoMS is based on repetition type A-like mechanism. |
| LG | Only if those for PUSCH repetition type A is reused. | For the TDW determination procedure, following is agreed in agenda 8.8.1.3 during previous meeting.  **Agreement**   * The TDW determination procedure agreed for PUSCH repetition type A is reused, when applicable, for PUSCH repetition type B and TBoMS with or without repetition. * No additional specification enhancements for PUSCH repetition type B and TBoMS   It is our understanding that actual TDW is determined based on the events which include frequency hopping, and configured/actual TDW is determined after hopping interval determination.  Therefore it is natural that inter-slot frequency hopping for TBoMS is supported only when inter-slot frequency hopping for PUSCH repetition type A is reused. |
| NTT DOCOMO | Yes |  |
| WILUS | Yes | Reuse mechanism for PUSCH repetition type A without additional enhancement for TBoMS. |
| China Telecom | Yes |  |
| Samsung |  | Rel-17 maintenance should not be used to introduce new features/optimizations. |
| Ericsson | Yes, but Rel-17 frequency hopping should be supported with and without DMRS bundling configured. | As we show in R1-2200660, there are gains from an enhanced frequency hopping pattern for TBoMS over Rel-15/16 frequency hopping. Similarly, we show in R1-2200657 that there are gains from such new hopping patterns when used with PUSCH repetition Type A and DMRS bundling. Therefore, we suggest to support Rel-17 frequency hopping patterns for TBoMS, with and without DMRS bundling being configured. |
| QC | Yes | We strive to use all features accessible to PUSCH Rep Type A to TBOMS as well. |
| ZTE | Yes | Optimization specific for TBoMS should be avoided. |
| CMCC | Yes | A better performance can be expected by supporting inter-slot frequency hopping with DMRS bundling for TBoMS. Same mechanism for type-A PUSCH repetition could be used. |
| Lenovo, Motorola Mobility | Yes | To exploit the benefit of joint channel estimation for all relevant cases |
| Xiaomi | Yes |  |
| OPPO | Yes |  |
| Huawei, HiSilicon | Yes | Share similar view as Nokia. |

Based on the feedback received, the following FL proposal is made.

**FL Proposal 4: The same mechanism of inter-slot frequency hopping with DMRS bundling for type-A PUSCH repetitions is reused for TBoMS.**

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Huawei, HiSilicon | Support. |
| CATT | Support. |
| Nokia/NSB | Support |
| China Telecom | Support. |
| Intel | We are fine with the proposal in principle. It may be good to clarify that this is for inter-slot frequency hopping with inter-slot bundling. For inter-slot frequency hopping, it was already agreed in TBoMS AI. Suggested update as follows:  **The same mechanism of inter-slot frequency hopping with inter-slot bundling for DMRS bundling for type-A PUSCH repetitions is reused for TBoMS.** |
| Ericsson | Support FL proposal 4 as written. |
| WILUS | Support. |
| Lenovo, Motorola Mobility | Support |
| LG | Support. |

## Other proposals

R1-2200280: Proposal 1: Candidate values of Frequency hopping interval can be any integer value that is equal or large than 1.

R1-2200280: Proposal 2: PUCCH, PUSCH repetition type A, TBoMS and PUSCH repetition type B can have separate configurations of inter-slot FH with DMRS bundling interval.

R1-2200423 Proposal 1: 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.

FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 3.1, 3.2, 3.3. But companies are welcome to provide comments to the above proposals in the following table.

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

# 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

|  |  |  |
| --- | --- | --- |
| [R1-2200054](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200054.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2200089](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200089.zip) | Remaining issues on PUCCH enhancements | vivo |
| [R1-2200114](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200114.zip) | Discussion on remaining issues for coverage enhancements for PUCCH | ZTE |
| [R1-2200153](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200153.zip) | Remaining issues on PUCCH enhancements | CATT |
| [R1-2200163](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200163.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [R1-2200208](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200208.zip) | PUCCH enhancements | Samsung |
| [R1-2200239](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200239.zip) | PUCCH enhancements for coverage enhancement | NTT DOCOMO, INC. |
| [R1-2200280](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200280.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2200304](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200304.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2200322](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200322.zip) | Discussion on the interaction between inter-slot frequency hopping and DMRS bundling | Panasonic Corporation |
| [R1-2200337](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200337.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2200382](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200382.zip) | Remaining details on PUCCH enhancements | Intel Corporation |
| [R1-2200423](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200423.zip) | Further discussion on PUCCH coverage enhancement | Apple |
| [R1-2200468](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200468.zip) | Discussion on PUCCH enhancements | xiaomi |
| [R1-2200488](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200488.zip) | Remaining issues on inter-slot frequency hopping with inter-slot bundling for PUCCH and PUSCH | China Telecom |
| [R1-2200502](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200502.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2200521](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200521.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2200591](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200591.zip) | Remaining issues on PUCCH enhancements | CMCC |
| [R1-2200614](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200614.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2200636](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200636.zip) | Remaining issues on PUCCH enhancements for coverage enhancement | WILUS Inc. |
| [R1-2200658](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107b-e/Docs/R1-2200658.zip) | Remaining Issues for PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |