**3GPP TSG RAN WG1 #108-e R1-** **220xxxx**

**e-Meeting, February 21st – March 3rd, 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

For PUCCH repetitions, there is a remaining RRC related issue from last RAN1 meeting.

**Remaining issue: Value range for PUSCH-Frequencyhopping-Interval and PUCCH-Frequencyhopping-Interval**

VIVO Proposal 1: The value range of frequency hopping interval is the same as the value range for the configured TDW length.

Xiaomi Proposal 3: The value range of PUCCH-Frequencyhopping-Interval can be the same as PUCCH-TimeDomainWindowLength, and the value range of PUSCH-Frequencyhopping-Interval can be the same as PUSCH-TimeDomainWindowLength.

CATT Proposal 3: Support the value range of {2,4,5,10} for PUCCH-Frequencyhopping-Interval and {2,4,5,8,10,16} for PUSCH-Frequencyhopping-Interval.

Panasonic Proposal 5: The value range of frequency hopping interval is {2, 4, 5, 8, 10} consecutive slots.

CT Proposal 2: The value range of PUCCH-Frequencyhopping-Interval at least includes {2,4,5} and the value range of PUSCH-Frequencyhopping-Interval can be {2,4,5,8,10,16,20}.

DCM Proposal 2: Value range of “PUSCH-Frequencyhopping-Interval” and “PUCCH-Frequencyhopping-Interval” should include at least 5 and 10 slots with considering TDD pattern.

Spreadtrum proposal 3: Value range for PUCCH-Frequencyhopping-Interval is set to “{2, 4, [5]}

Spreadtrum proposal 4: for PUSCH-Frequencyhopping-Interval, down select between:

* 1. Value range for PUSCH-Frequencyhopping-Interval is set to “{1,2,4,5,8,10,16,20}, when PUSCH repetition Type B is configured, value shall not exceed the duration of PUSCH repetition Type B
  2. Value range for PUSCH-Frequencyhopping-Interval is set to “{1,2,4,5,8,10,16,20} for PUSCH repetition Type A, and a new parameter PUSCH-RepTypeB-Frequencyhopping-Interval is set to {1,2,4,5,8,10}

CMCC Proposal 3：The value range for PUCCH-Frequencyhopping-Interval is set to “{2, 4,}” or “{1, 2, 4, 8}”, the second one is preferred.

Ericsson Proposal 5:

* For both PUSCH-Frequencyhopping-Interval and PUCCH-Frequencyhopping-Interval, the value range to be specified is selected taking into account TDD configurations.
  + A maximum value of no less than 10 slots is specified
  + Whether or not a maximum value of more than 10 slots is specified is further discussed.

Samsung Proposal 5:

* Value range for PUCCH-Frequencyhopping-Interval is “{2, 4}”
* Value range for PUSCH-Frequencyhopping-Interval is “{1, 2, 3, 4, 6, 7, 8, 10, 12, 14, 16}”

Apparently, given different companies may have different interested use cases in mind, the views on this issue are quite diverged. FL’s initial recommendation is to take a super set of all proposed values so that the spec could allow all meaningful use cases.

**FL proposal 1:**

* Value range for PUCCH-Frequencyhopping-Interval is “{1, 2, 4, 5, 8, 10}”
* Value range for PUSCH-Frequencyhopping-Interval is “{1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20}”

Please provide comments to the above proposal, if any, in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| vivo | Generally fine.  For value ‘1’, we would like to clarify the intention? The following interpretations are what we have in mind.  - interpretation-1: fall back to legacy inter-slot frequency hopping for type-A PUSCH repetition? For this interpretation, legacy frequency hopping pattern **w/o** DMRS bundling is enabled by a new RRC configuration, we wonder whether such optimization is in scope.  - interpretation-2: phase continuity and power consistency should be ensured within a slot for sub-slot based PUCCH repetition (which is supported in R17 URLLC). for this interpretation, we have deprioritized B2B and non-B2B PUCCH repetitions with in a slot in previous meetings.  - interpretation-3: for type-B PUSCH repetition, phase continuity and power consistency should be ensured across actual PUSCH repetitions within a slot. If this value is used only for repetition type-B, we have agreed that the same mechanism as for type-A PUSCH repetitions is used for type-B PUSCH repetition, we are not sure whether we need to have a value only applicable for type-B PUSCH repetition. |
| Huawei, HiSilicon | For unpaired spectrum, at least {5,10} should be supported.  As discussed last meeting, the values 4, 7, 8, 12, 14, 16 need more justification because they have more spec impacts than other values. To be specific, PUSCH FH pattern in current spec is based on physical slot index without involving system frame number (S6.3.1 of TS 38.214). However, since value 4, 7, 8, 12, 14, 16 slots cannot divide 10 nor 20 slots which is the typical number of slots in one radio frame, the proposal implies more spec impacts to involve SFN into the FH patterning determination. We would like to ask proponents for clarification on this.  If the values were motivated by TDD UL/DL configurations, then at least the interval should be able to divide 20ms because all slot configuration periods (P or P+P2) (S11 of TS 38.213) divide 20ms.  Therefore, we suggest that all the potential values should be able to divide 20ms. |
| Intel | It is not clear to us why {1} is included as hopping interval for both PUSCH and PUCCH.  We already support inter-slot frequency hopping in Rel-15/16. It seems redundant to support inter-slot frequency hopping with inter-slot bundling, but with hopping interval = 1. This is equivalent to inter-slot frequency hopping in Rel-15/16.  For PUSCH frequency hopping interval, it may be good to clarify the motivation to configure large hopping interval, e.g., {14, 16, 20}. We do not see the need for these large values. |
| Samsung | A maximum value not larger than half the number of repetitions seems to be sufficient so that frequency hopping can be enabled with 2 hops when these parameters are provided.  [1] is not needed. |
| Nokia/NSB | We object the inclusion of [1] in the list of values since this value would implicitly disable DM-RS bundling regardless of the value of *PUCCH-DMRS-Bundling* and *PUSCH-DMRS-Bundling*. This behavior goes against the principle upon which the activation of DM-RS bundling has been designed, and against the agreed description of such parameters RAN1 provided to RAN2, i.e., “Enabling/disabling of DM-RS bundling and time domain window for PUCCH repetitions.” and “enabling/disabling of DM-RS bundling and time domain window for PUSCH repetitions.”. Indeed, if FH interval duration is set to 1, then the *PUCCH-DMRS-Bundling* and *PUSCH-DMRS-Bundling* could enable DM-RS bundling for PUSCH and PUCCH if and only if the configured FH interval is larger than 1. Moreover, if it will be agreed that physical slot index is used for FH interval determination of PUCCH, then setting FH interval length equal to 1 would imply that FH behavior for PUCCH in Rel-17 is different from Rel-16 counterpart, even when DM-RS bundling is not used. This is not acceptable.  Concerning the remaining values, we think that a decision cannot be taken unless we first define which slot index is used to determine the hops (physical or relative). More precisely, if physical slot index is used than the concern expressed by Huawei is valid and values different from {2, 5, 10} should not be supported to avoid complicating the specification with no sound technical reasons. Conversely, if relative slot index is used, then values different from {2,5,10} can be supported without large specification impact, although the motivation for supporting values larger than 8 for PUCCH would be unclear in this case. |
| QC | For PUCCH repetitions, from a FDD perspective, we think values 2 and 4 suffice. From a TDD perspective, multiples of 5 might be helpful (for e.g. 5 and 10). The pattern should repeat itself every frame i.e., dependence only on slot index.  For PUSCH repetitions, from a FDD perspective, we think values 2,4, and 8 suffice. From a TDD perspective, multiples of 5 might be helpful (for e.g. 5 and 10). The pattern should repeat itself every frame i.e., dependence only on slot index.  Okay if the interval does not divide the number of slots in a frame --- the last hop is a bit shorter. |

# 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

IDC Proposal 1: The dynamic PUCCH repetition factor indication applies to HARQ-ACK corresponding to the SPS release DCI.

IDC Proposal 2: The dynamic PUCCH repetition factor indication applies to the HARQ-ACK corresponding to SPS PDSCH received after SPS activation DCI in case SPS-PUCCH-AN-List is not configured.

Intel Proposal 1

* Dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH which is not associated with or activated by a DCI is not supported.
* No TP is needed for dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH which is not associated with or activated by a DCI.

Ericsson Proposal 1:

* Revise the moderator’s updated proposed 2 RAN1#107bis to the following:
  + 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

In FL’s understanding, this open issue is heavily related to a Rel-15/16 maintenance issue which is discussed under [108-e-NR-CRs-02]. FL suggest to not discuss this open issue until the email thread [108-e-NR-CRs-02] is concluded.

## Other proposals

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

Apple proposed Conclusion 1: No new value for the maximum number of PUCCH resources within each resource set is defined in Rel-17.

FL’s initial assessment is that the discussion of this proposal can be deprioritized. But companies are welcome to provide comments to the above proposals in the following table.

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

# 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)**

In RAN1 107bis-e, the following agreement was made.

**Agreement**

**PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as a [semi-static] event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions.**

The remaining issue is whether to confirm the above event is a “semi-static” event. The proposals to address this issue are summarized as below.

Nokia Proposal 1. RAN1 to remove square brackets and agree the following: “PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as a semi-static event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions.”

VIVO Proposal 2: PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as semi-static event.

Intel Proposal 2

* PUCCH repetitions with UL beams switching and different sets of power control parameters for multi-TRP operation is regarded as a semi-static event.

Based on the above proposals, the following FL proposal is made.

**FL proposal 2: update the following agreement made in RAN1 107bis-e as below**

**Agreement**

**PUCCH repetitions with different sets of power control parameters in multi-TRP operation should be regarded as a ~~[~~semi-static~~]~~ event that causes power consistency and phase continuity not to be maintained across PUCCH repetitions.**

Please provide comments to the above FL proposal, if any, in the table below.

|  |  |
| --- | --- |
| **Company name** | **comment** |
| Vivo | support |
| Huawei, HiSilicon | Support. |
| Intel | We are fine with the FL proposal 2. |
| Samsung | OK with the proposed updated agreement. |
| Nokia/NSB | Support. |
| QC | Support |

Furthermore, the following TP was provided in R1-2201711, which is related to this open issue.

**------------------------------ TP#1: TS 38.214-----------------------------------**

6.1.7 UE procedure for determining time domain windows for bundling DM-RS

**< Unchanged text omitted >**

The UE shall maintain power consistency and phase continuity within an actual TDW, across PUSCH transmissions of PUSCH repetition Type A scheduled by DCI format 0\_1 or 0\_2, or PUSCH repetition Type A with a configured grant, or PUSCH repetition type B or TB processing over multiple slots, or across PUCCH transmissions of PUCCH repetition, in case the actual TDW is created in response to frequency hopping, or in response to the use of a different SRS resource set association for the two PUSCH transmissions of PUSCH repetition type A, or PUSCH repetition type B, ~~[~~or in response to the use of different spatial relations or different power control parameters for the two PUCCH transmissions of PUCCH repetition,~~]~~ or in response to any event not triggered by DCI or MAC-CE. The UE maintains power consistency and phase continuity within an actual TDW, across PUSCH transmissions of PUSCH repetition Type A scheduled by DCI format 0\_1 or 0\_2, or PUSCH repetition Type A with a configured grant, or PUSCH repetition type B or TB processing over multiple slots, or across PUCCH transmissions of PUCCH repetition, in case the actual TDW is created in response to an event triggered by DCI other than frequency hopping or by MAC-CE, subject to UE capability.

**< Unchanged text omitted >**

**------------------------------ end of TP#1: TS 38.214-----------------------------------**

**FL question 1: What is your view on the above TP? Is it agreeable?**

|  |  |
| --- | --- |
| **Company name** | **comment** |
| vivo | support. |
| Huawei, HiSilicon | The term “power control parameters” is broad and can unnecessarily include some RAN4 parameters that are up to UE implementation, e.g. P-MPR. Additionally, it should be only related to uplink power control instead of downlink power control.  Therefore, suggest to replace it with “or different higher layer parameters of uplink power control” |
| Intel | We are fine with the TP. |
| Samsung | Perhaps mTRP operation be mentioned. |
| Nokia/NSB | Support. |

## 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

HW Proposal 1: Different rules to determine the inter-slot frequency hopping with DMRS bundling for PUSCH repetition and PUCCH repetition are preferred.

* For PUSCH repetition, the inter-slot frequency hopping with DMRS bundling is determined based on the physical slot indices;
* For PUCCH repetition, the inter-slot frequency hopping with DMRS bundling is determined based on the relative physical slot indices.

Nokia Proposal 2. 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

Nokia Proposal 3. 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, upon condition that the frequency hopping interval length is larger than 1 slot.

VIVO Proposal 3: Physical slot index is used for PUSCH hopping pattern determination, and relative slot index is used for PUCCH hopping pattern determination.

ZTE Proposal 2: For inter-slot frequency hopping for PUCCH/PUSCH with DMRS bundling.

* 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.

CATT Proposal 2: Physical slot index is used to determine inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.

Panasonic Proposal 1: Either of following option is taken.

* Option 1: Frequency hopping pattern is determined by physical slot indices for both PUSCH and PUCCH.
* Option 2: Frequency hopping pattern is determined by physical slot indices for PUSCH and is determined by relative slot indices for PUCCH.
* 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.

CT Proposal 1: For inter-slot frequency hopping for PUCCH/PUSCH with DMRS bundling, physical slot index is used to determine inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.

DCM Proposal 1: Physical slot index is used for PUSCH and relative slot index is used for PUCCH to align with current mechanism.

Spreadtrum Proposal 1: For inter-slot frequency hopping for PUCCH/PUSCH with DMRS bundling, Option 1: Physical slot index is used to determine inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.

Intel 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.

Apple Proposal 1: For DMRS bundling with frequency hopping, the first hopping interval starts relative to scheduling DCI and/or the first repetition occasion. The subsequent intervals are determined based on a fixed (not floating) hopping pattern.

CMCC Proposal 2: Frequency hopping pattern should be determined by physical slot indices.

Xiaomi Proposal 2: Frequency hopping pattern can be determined by physical slot indices.

Ericsson 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).

Samsung Proposal 1: For PUCCH repetitions with DM-RS bundling enabled, the frequency hopping pattern is determined based on a relative slot index as in Rel-16 (and as in Rel-17 when DM-RS bundling is not enabled).

Samsung Proposal 2: For PUSCH repetitions with DM-RS bundling enabled, the frequency hopping pattern is determined based on a physical slot index as in Rel-16 (and as in Rel-17 when DM-RS bundling is not enabled).

QC Proposal 1: Frequency hopping pattern for DMRS bundling across PUCCH transmissions is determined based on physical slot indices.

Sharp Proposal 3: The unified design of the hopping pattern should be applied to both PUSCH and PUCCH with DMRS bundling.

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

TCL Proposal 1: For inter-slot frequency hopping for PUCCH/PUSCH with DMRS bundling, option 4 is preferred.

* 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.

LG Proposal 1: The frequency hopping pattern for inter-slot frequency hopping is determined only by physical slot index.

WILUS 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, it is observed that the views on this issue are still diverged. Furthermore, based on FL’s understanding of companies’ proposals, among the companies supporting using relative slot index, there seems two ways to count relative slot index. Before we make a decision to use physical slot index or relative slot index, a discussion is needed to clarify how relative slot index is counted.

The two options to count relative slot index are listed as following, and illustrate by Figure 1.

* Option A: frequency hopping pattern is determined based on relative slot index. Relative slot 0 is the slot where PUCCH/PUSCH repetition starts. Each of the subsequent slots are counted and relative slot index increase by one **regardless** the slot is used to transmit PUCCH/PUSCH or not.
* Option B: frequency hopping pattern is determined based on available slot index. Relative slot 0 is the slot where PUCCH/PUSCH repetition starts. One of the subsequent slots are counted and the slot index increase by one **only if** the slot is used to transmit PUCCH/PUSCH.



Figure 1. Different options for relative slot index counting

Based on the above example, relative slot index – option B can achieve balanced hopping pattern in TDD regardless of TDD pattern. Relative slot index – option A seems just a shift version of physical slot index.

The benefits/drawbacks of each option are listed as below.

* Frequency hopping based on physical slot can pair/multiplex UEs with hopping in a more spectrum efficient fashion. However, R1-2201015 identifies that this benefit may not hold in case of different frequency hopping intervals are used cross UEs, as illustrated in the following Figure 2. FL’s assessment is that indeed the benefit of UE pairing/multiplexing with physical slot based hopping only holds among UEs with same hopping intervals. The drawback of using physical slot index to determine frequency hopping interval is also obvious, which would lead to unbalanced hopping intervals in TDD due to UL/DL pattern. Even in FDD, due to unaligned hopping boundary and TDW boundary, the hopping interval could be unbalanced, as mentioned in R1-2201167. However, it is FL’s understanding that gNB can configure hopping boundary to be aligned with TDW boundary to avoid this issue in FDD.
* Frequency hopping based on relative slot – option B can achieve more balanced hopping intervals, according to R1-2201015, which is also obviously shown in above Figure 1. But the drawbacks of option B is that it is deviation from the legacy approach to determine hopping interval.
* Frequency hopping based on relative slot – option A seems just a time shift version of frequency hopping based physical slot index, as shown in Figure 1. In TDD, the benefit of option A is not clear. In FL understanding, in TDD, it can neither achieve balanced hopping interval nor pair users better to improve spectrum efficiency. In FDD, option A is identical to option B, which has the benefit of more balanced hopping intervals.

Graphical user interface, application

Description automatically generated

Figure 2. Frequency multiplexing of frequency hopping UEs with different hopping patterns

In summary, the benefits/drawbacks of different options are captured in the following table

|  |  |  |  |
| --- | --- | --- | --- |
|  | Frequency hopping based on Physical slot index | Frequency hopping based on relative slot index – option A | Frequency hopping based on relative slot index – option B |
| TDD | Pros: More spectrum efficient MU pairing (requires same freq hopping interval)  Cons: unbalanced hopping intervals | Pros: not identified so far  Cons: unfriendly to MU pairing | Pros: balanced hopping intervals  Cons: unfriendly to MU pairing |
| FDD | Pros: More spectrum efficient users pairing (requires same freq hopping interval)  Pros: balanced hopping interval with aligned TDW  Cons: unbalanced hopping interval with misaligned TDW | Pros: balanced hopping interval  Cons: unfriendly to MU pairing | Pros: balanced hopping intervals  Cons: unfriendly to MU pairing |

Before making a recommend proposal, FL would like to collect more input, especially on whether anything is missed in the analysis of the pros/cons of different hopping determination options as listed in the above table.

**FL question 2: Anything comment in the above table regarding the assessment of the pros/cons of the three different options to determine frequency hopping interval?**

|  |  |
| --- | --- |
| **Company name** | **comment** |
| Huawei, HiSilicon | We feel Option B may suffer from DCI misdetection or false alarm if it relies on DCI to determine whether a slot is transmitted and whether there is a frequency hopping. Better to clarify whether it is dynamic or semi-static determination on slot transmission with respect to the concept of Option B.  Regarding unbalanced hopping intervals, not sure if it is an important aspect. Even it is important, such unbalance can be mitigated by scheduling a UE with a different starting hopping position from that position for its preceding scheduling, e.g. if the 1st scheduled repetitions (by 1st DCI) starts hopping at the left half of a UE bandwidth, then the 2nd scheduled repetitions (by 2nd DCI) starts hopping at the right half of a UE bandwidth. |
| Intel | Our view is that extension of existing mechanisms should be one of the most important factors to be considered to determine the frequency hopping pattern, which would minimize the spec impact and UE implementation effort. In particular, 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 |
| Samsung | As this discussion is about applying frequency hopping when DM-RS bundling is enabled, we don’t support changing Rel-16 frequency hopping for either PUSCH or PUCCH for this case when no issue has been identified. MU pairing seems not to be one. |
| Nokia/NSB | We agree with most of the FL’s analysis of the situation. The best performance is surely delivered by Option B of relative slot index. Option A is based on a straightforward extension of the legacy behavior which does not seem to yield performance improvement at first glance. However, and differently from the physical slot approach it still yields a more flexible approach to FH interval duration configuration, while ensuring simpler spec impact (please see discussion on RRC parameters in Section 2). |
| QC | We are okay with the FL summary. Going forward, we prefer to focus on only two options: (a) hop pattern based on physical slot indices and (b) hop pattern based on relative slot indices with Option A.  Option B does not seem compatible with how we think of frequency hopping interval --- a set of consecutive slots. |

**FL question 3: Inter-slot frequency hopping for PUCCH with DMRS bundling should be determined based on**

**physical slot index, or relative slot index – option A, or relative slot index – option B?**

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Vivo | Relative slot index-option A, and we are also fine with frequency hopping based on physical slot index. |
| Huawei, HiSilicon | In current spec, the inter-slot frequency hopping for PUCCH repetitions is determined based on relative slot index, and the relative slot index is increased by one regardless of the slot is used to transmit PUCCH or not. So option A is preferred where the inter-slot frequency hopping for PUCCH with DMRS bundling is determined based on relative slot index. Regarding option B, as commented above, balanced hopping interval is an observation only based on single scheduling. For multiple scheduling instances, it is not important aspect and can be mitigated by gNB scheduling if needed. |
| Intel | We support relative slot index – Option A. This is extension of existing mechanism. |
| Samsung | For PUCCH - relative slot index. No reason to change Rel-16 FH for PUCCH when DM-RS bundling is enabled. |
| Nokia/NSB | Prefer relative slot index – Option B. Can live with Option A. |
| QC | We prefer hop pattern based on physical slot indices for both PUCCH and PUSCH. |

**FL question 4: Inter-slot frequency hopping for PUSCH with DMRS bundling should be determined based on**

**physical slot index, or relative slot index – option A, or relative slot index – option B?**

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Vivo | Physical slot index |
| Huawei, HiSilicon | In current spec, the inter-slot frequency hopping for PUSCH repetitions is determined based on physical slot index. So reusing the existing mechanism is preferred. |
| Intel | We support physical slot index. This is extension of existing mechanism. |
| Samsung | For PUSCH - physical slot index. No reason to change Rel-16 FH for PUSCH when DM-RS bundling is enabled. |
| Nokia/NSB | Prefer relative slot index – Option B. Can live with Option A. Physical slot index cannot be accepted if [1] is not excluded from the list of configurable FH interval values, for the reasons explained in Section 2. |
| QC | We prefer hop pattern based on physical slot indices for both PUCCH and PUSCH. |

**FL question 5: If no convergence can be achieved, is the following conclusion acceptable?**

* **Rel-17 does not support inter-slot frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling.**

|  |  |
| --- | --- |
| **Company name** | **Answer** |
| Intel | We do not support the proposal.  In our view, inter-slot frequency hopping with inter-slot bundling, in conjunction with DMRS bundling is an important feature for coverage enhancement. This has been great effort in RAN1 for this feature and it would be really unfortunate that this is not supported in Rel-17. |
| Samsung | It is not clear the intent of this proposal. The default is existent specifications - if there is no consensus in changing a Rel-16 operation (frequency hopping) when an agreed Rel-17 feature is enabled (DM-RS bundling), Rel-16 operation should be maintained. This is the same principle used in FL Proposed conclusion 1 in next section – it should be applied here as well. |
| Nokia/NSB | We prefer discussing a bit more before starting to consider this kind of proposals. |
| QC | Lets try to find common ground. Will be good to have this feature. |

### FFS: details of FH pattern design

HW Proposal 5: It is not necessary to increase the number of frequency offsets over what are supported in Rel-15/16.

Ericsson Proposal 2:

* Enhanced frequency hopping designs for PUCCH and PUSCH include the following:
  + - Increased hopping offsets over Rel-15 are supported, e.g. M=4,

Samsung Proposal 4:

For PUCCH and PUSCH repetitions with DM-RS bundling enabled, the number of frequency hops is two.

HW Proposal 2: In case of inter-slot frequency hopping with DMRS bundling for PUSCH repetition, the starting RB during slot is given by:

where is the current slot number within a radio frame, is the starting RB with the UL BWP, is the frequency offset in RBs between the two frequency hops, and is the interval of the frequency hopping indicated by PUSCH-Frequencyhopping-Interval.

HW Proposal 3: In case of inter-slot frequency hopping with DMRS bundling for PUCCH repetition, the starting RB during slot is given by:

where the slot indicated to the UE for the first PUCCH transmission has number 0, i.e., , the each subsequent slot until the UE transmits the PUCCH in slots is counted regardless of whether or not the UE transmits PUCCH in the slot, is the starting RB with the UL BWP, is the frequency offset in RBs between the two frequency hops, and is the interval of the frequency hopping indicated by PUCCH-Frequencyhopping-Interval.

OPPO proposed TP1:



* +  is the current slot physical number not consider frame boundary
  + 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
  + H is hopping interval in number of slots

CATT Proposal 1: System frame nuber should be introduced to determine the hopping pattern:

Panasonic 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

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.

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

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

* Issue 1: Whether increase the number of frequency offset over Rel-15/16 are supported?
* Issue 2: What is the exact equation to decide hopping pattern?

For issue 2, the solution depends on the decision for questions in Section 4.2.1. FL suggest putting the discussion on issue 3 on hold until the open issues in Section 4.2.1 are resolved. For issue 1, based on the discussion in last meeting and also checking the input from companies’ contributions submitted to this meeting, it is FL’s initial assessment that there is no consensus to support increased the number of frequency offset over what are supported in Rel-15/16. Therefore, FL recommend to agree on the following conclusion to close this open issue 1.

**FL Proposed conclusion 1: For frequency hopping for PUCCH/PUSCH repetitions with DMRS bundling, in Rel-17, there is no consensus to increase the number of frequency offset over what are supported in Rel-15/16.**

Further comments on the above proposed conclusion can be added in the following table.

|  |  |
| --- | --- |
| **Company name** | **comment** |
| Vivo | Support. |
| Huawei, HiSilicon | Support.  Additionally, according to the following agreement, we feel that increased number of frequency offset for PUSCH frequency hopping **without** DMRS bundling has been precluded.  Agreement:   * For Rel-17 PUSCH repetition Type A without joint channel estimation, no new inter-slot frequency hopping mechanism is introduced. |
| Intel | We support the FL Proposed conclusion 1 |
| Samsung | OK |
| Nokia/NSB | Ok |

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

In RAN1-107bis, the following four options were discussed 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, TCL (conditioning on DMRS bundling enabled)
* **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: TCL(conditioning on DMRS bundling is disabled), Panasonic (conditioning on DMRS bundling is disabled), WILUS, QC

In RAN1 108e, the following proposals are submitted to address this issue. It is FL’s initial assessment that companies views on this open issue are not changed comparing to RAN1 107-bis-e.

HW Proposal 4: In the case of both frequency hopping interval and TDW length are not configured, the default frequency hopping interval is the default TDW length, i.e., min(maximum duration, duration of all PUSCH/PUCCH repetitions).

Nokia Proposal 4. Set the frequency hopping interval length equal to the default configured TDW length, in the case the configured TDW length is not configured, and the frequency hopping interval is not configured

VIVO Proposal 5: Support option 2 as the default hopping interval

ZTE 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. (Option 1)

OPPO Proposal1: If inter-slot is enabled but hopping interval and window length L are not configured, UE expected PUCCH-bundling is not enabled.

Panasonic 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.

Spreadtrum Proposal 2: Support 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.

IDC Proposal 3: 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.

Intel Proposal 3

* For inter-slot frequency hopping with inter-slot bundling
  + If hopping interval and TDW length are not configured, default hopping interval is half of default window length of the configured TDW.

Xiaomi Proposal 4: If both hopping interval and TDW length L are not configured, the hopping interval can be the same as the default TDW length L = min (maximum duration, duration of all PUSCH repetitions).

Samsung proposal 3: For PUCCH and PUSCH repetitions with DM-RS bundling enabled, if configuration of frequency hopping interval is not provided and configuration of TDW length is not provided, the default value of the frequency hopping interval is half the number of repetitions.

TCL Proposal 2: If DMRS-bundling is enabled, option 2 is preferred. Otherwise, option 4 is preferred.

LG Proposal 3: 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.

WILUS 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.

The pros/cons of the 4 options are summarized as below

|  |  |
| --- | --- |
|  | Summary of pros/cons of the four options |
| Option 1 | Option 1 can explore hopping gain with two equal length hopping intervals, even when hopping interval is not configured, which potentially achieves balanced tradeoff between hopping diversity gain and DMRS bundling gain |
| Option 2 | Option 2 is the most natural extension of current agreement/specification. Option 2 can still explore hopping diversity gain if maximum < duration of all PUSCH/PUCCH repetitions. Option 2 cannot explore hopping diversity gain (while still maximizing DMRS bundling gain) if maximum > duration of all PUSCH/PUCCH repetitions. |
| Option 3 | Option 3 is very similar to option 1. Based on analysis in R1-2201167, option 1 seems better than option 3. |
| Option 4 | If hopping interval is not configuration Option 4 seems effectively disabling DMRS bundling, which seems an unnecessary outcome. |

Given the pros/cons of the options and the number of companies supporting each option, FL recommend to focus on further discussion on option 1 and option 2 and remove option 3 and 4.

**FL Proposal 3: For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, in the case of both** **frequency hopping interval and TDW length are not configured, down-selection from the following two options to determine the default frequency hopping interval for PUCCH/PUSCH repetitions**

* **Option 1: the default frequency hopping interval is half duration of PUCCH/PUSCH repetitions**
* **Option 2: the default frequency hopping interval is the default window length of the configured TDW**

Please provide comments, if any, to the above proposal in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Vivo | Option 2.  According to the agreements in RAN1#107 e-meeting, if hopping interval is not configured, the default frequency hopping interval equals the configured TDW length, and the default TDW length would be the minimum one between the maximum duration and duration of all PUSCH/PUCCH repetitions if TDW length is not configured, it is clear that the default frequency hopping interval is the default window length of the configured TDW.  Moreover, if a certain hopping interval length is expected by NW, an explicit RRC configuration can be provided to UE. |
| Huawei, HiSilicon | The motivation to support option 1 is not clear. If any gain can be achieved by Option 1, then a gNB can configure it directly. Therefore, option 2 is preferred. |
| Intel | We are fine with the proposal in principle. For Option 1, we suggest to modify this as “the half of the default window length of the configured TDW”. Note that default window length of the configured TDW depends on both repetition duration and configured TDW duration. It would be good not to only limit this to repetition duration.  Based on this, the Proposal 3 can be updated to  **FL Proposal 3: For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, in the case of both frequency hopping interval and TDW length are not configured, down-selection from the following two options to determine the default frequency hopping interval for PUCCH/PUSCH repetitions**   * **Option 1: the default frequency hopping interval is half of the default window length of the configured TDW ~~duration of PUCCH/PUSCH repetitions~~** * **Option 2: the default frequency hopping interval is the default window length of the configured TDW** |
| Samsung | The reason for supporting Option 1 is to be able to enhance performance by using frequency hopping when DM-RS bundling is enabled. |
| Nokia/NSB | Fully agree with vivo and Huawei/HiSilicon. We are not even sure this discussion is needed, since we have a default behavior for cTDW when this is not configured, and we have a default behavior for FH interval when this is not configured. |

## Other proposals

OPPO Proposal 2: Time domain windows for bundling PUCCH DM-RS is to be moved from 6.1.7 38.214 to 38.213.

Panasonic Proposal 6: The value “1” of frequency hopping interval can be added with the condition that it is supported only for PUSCH repetition Type B or sub-slot-based PUCCH repetition.

CMCC Proposal 1: The details and the differences between the slot-based and sub-slot-based repetition may still need more discussion.

LG Proposal 4: The bundle size can be same as or different from the time domain window size.

WILUS 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.

FL’s initial assessment is that the discussion of those proposals can be deprioritized. 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

|  |  |  |
| --- | --- | --- |
| [R1-2200969](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2200969.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2201015](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201015.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [R1-2201107](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201107.zip) | Remaining issues on PUCCH enhancements | vivo |
| [R1-2201167](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201167.zip) | Discussion on remaining issues for coverage enhancements for PUCCH | ZTE |
| [R1-2201286](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201286.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2201376](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201376.zip) | Remaining issues on PUCCH enhancement | CATT |
| [R1-2201382](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201382.zip) | Discussion on the interaction between inter-slot frequency hopping and DMRS bundling | Panasonic Corporation |
| [R1-2201445](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201445.zip) | Remaining issues on inter-slot frequency hopping with inter-slot bundling | China Telecom |
| [R1-2201490](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201490.zip) | Remaining issues on PUCCH enhancement | NTT DOCOMO, INC. |
| [R1-2201556](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201556.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2201660](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201660.zip) | Discussion on PUCCH enhancements | InterDigital, Inc. |
| [R1-2201711](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201711.zip) | Remaining details on PUCCH enhancements | Intel Corporation |
| [R1-2201783](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201783.zip) | Remaining issues on PUCCH coverage enhancement | Apple |
| [R1-2201871](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201871.zip) | Remaining issues on PUCCH enhancements | CMCC |
| [R1-2201913](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201913.zip) | Remaing issues on PUCCH enhancements | Xiaomi |
| [R1-2201964](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2201964.zip) | Remaining Issues for PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [R1-2202029](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202029.zip) | PUCCH enhancements | Samsung |
| [R1-2202154](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202154.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2202199](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202199.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2202238](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202238.zip) | Discussion on PUCCH enhancements | TCL Communication Ltd. |
| [R1-2202302](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202302.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2202488](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_108-e/Docs/R1-2202488.zip) | Remaining issues on PUCCH enhancements for coverage enhancement | WILUS Inc. |