**3GPP TSG RAN WG1 #107-e R1-211xxxx**

**e-Meeting, November 11th – 19th, 2021**

**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.

# Dynamic PUCCH repetition factor indication

## Whether semi-static PUCCH can use a PUCCH resource with “nrofSlots-r17” configured

Regarding whether dynamic PUCCH repetition factor indication should be applied to semi-static PUCCH, the following agreement is made in RAN1 106e.

**Agreement**

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

With the above agreement, in R1-2109889 and R1-2110866, a potential ambiguity is observed. The ambiguity is that whether SR or P/SP-CSI on PUCCH can utilize a PUCCH resource configured with repetition factor “nrofSlots-r17”. The following proposal is made, which basically allow UE to use the PUCCH resource configured with repetition factor “nrofSlots-r17”. But UE ignore the RRC parameter “nrofSlots-r17” and use the legacy RRC parameter nrofSlots to determine the repetition factor for this particular PUCCH resource.

R1-2109889 & R1-2110866, Proposal 1: in the case a PUCCH resource is not associated with a scheduling DCI (e.g. PUCCH resource associated with CSI report) and the PUCCH resource is characterized by a dynamic repetition factor, the parameter nrofSlots is used for determining the repetition factor of the specific PUCCH resource.

After discussing the above issue in RAN1#106bis, the following FL proposal was made. The FL proposal seems supported by majority companies. But no agreement was made on this due to limited discussion time. Therefore, FL would like to repropose the following.

FL proposal 1: **For a PUCCH resource to transmit a PUCCH without an associated scheduling DCI (e.g. P/SP-CSI or SR), if the PUCCH resource is configured with RRC parameter “nrofSlots-r17”, “nrofSlots-r17” is ignored and the RRC parameter “nrofSlots” is used for determining the repetition factor of the specific PUCCH resource.**

Companies are welcome to provide further comments to the above FL proposal

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | In our view, the above agreement means the repetition factor for SP or P/SP-CSI on PUCCH is not dynamically indicated. If “nrofSlots-r17” is configured on a PUCCH resource for the PUCCH without the associated scheduling DCI, the PUCCH resource and “nrofSlots-r17” are not dynamically indicated. Therefore, we think no special handling is needed (i.e., ignoring “nrofSlots-r17” is not needed).  However, we are OK with the proposal if the majority supports it. |
| Panasonic | We are fine with the FL proposal 1. |
| Nokia/NSB | Support |
| China Telecom | We support this proposal. |
| CATT | Support. |
| vivo | Support |
| ZTE | Fine with the proposal |
| CMCC | Fine with the FL proposal 1. |
| Intel | We are fine with the proposal. |
| Apple | Support FL’s proposal |
| Ericsson | Support |
| Lenovo, Motorola Mobility | Support the proposal |

## 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. however, it was not agreeable due to controversial views.

Updated FL proposed conclusion 0: In NR Rel-17, the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e does not apply to HARQ-ACK for SPS PDSCH except for the following two cases

* HARQ-ACK for the first SPS PDSCH associated with the activation DCI.
* HARQ-ACK corresponding to the SPS release DCI

Note: HARQ-ACK for the first SPS PDSCH associated with the activation DCI and HARQ-ACK corresponding to the SPS release DCI are categorized as PUCCH with associated scheduling DCI

In this meeting, companies input on this topic is listed as below.

R1-2111439 Proposal 1: The dynamic PUCCH repetition factor indication mechanism does not apply to HARQ-ACK for SPS PDSCH except for the following two cases.

* HARQ-ACK for the first SPS PDSCH associated with the activation DCI
* HARQ-ACK corresponding to the SPS release DCI

R1-2110921 Proposal 1: Dynamic PUCCH repetition indication is supported for HARQ-ACK for the first SPS PDSCH with associated with the activation DCI and HARQ-ACK corresponding to the SPS release DCI, while not supported for HARQ-ACK for the remaining SPS PDSCHs other than the first SPS PDSCH.

R1-2112233 Proposal 2: Support dynamic PUCCH repetition indication for HARQ-ACK for the first SPS PDSCH associated with the activation DCI.

R1-2111510 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.

R1-2111754 Proposal 1: Conclusion

In NR Rel-17, the dynamic PUCCH repetition factor indication mechanism agreed in RAN1#106-e does not apply to HARQ-ACK for SPS PDSCH except for

* HARQ-ACK corresponding to the SPS release DCI

Note: The resource for HARQ-ACK for the first SPS PDSCH associated with the activation DCI is configured in SPS-Config by n1PUCCH-AN as a single PUCCH resource.

R1-2112038 Proposal 1:

* Revise the moderator’s updated proposed conclusion 0 from RAN1#106bis to the following:
  + In NR Rel-17, the dynamic PUCCH repetition factor indication mechanism agreed in RAN1 106e does not apply to HARQ-ACK for SPS only operation

Based on the companies’ input, for HARQ-ACK of SPS release DCI, it seem common understanding that dynamic PUCCH repetition factor indication can be applied. For HARQ-ACK of the first SPS PDSCH with activation DCI, the views are still controversial.

Therefore, the following FL proposal is made.

**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.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | OK |
| Panasonic | We are fine with the FL proposed conclusion 1.  On FFS point, i.e., whether HARQ-ACK for the first SPS PDSCH associated with the activation DCI is categorized as dynamic PUCCH or semi-static PUCCH, the same handling as Rel.15/16 should be taken. |
| Nokia/NSB | We do not agree with logic provided in R1-2111754. Clause 9.2.3 of TS 38.213 does not differentiate between scheduling/activation/triggering DCI, but rather refers to a corresponding PDCCH.   |  | | --- | | If a UE is not provided SPS-PUCCH-AN-List and transmits HARQ-ACK information corresponding only to a PDSCH reception without a corresponding PDCCH, a PUCCH resource for corresponding PUCCH transmission with HARQ-ACK information is provided by n1PUCCH-AN. |   In our view, the common understanding in RAN1 is that a corresponding PDCCH is any PDCCH which carries a DCI which used by UE to locate/receive a subsequent PDSCH. We acknowledge that some ambiguity may exist w.r.t. the so-called activation DCI, at least in terms of terminology, however such ambiguity does not exist in terms of meaning. In this context, we may want to note that this understanding is the same used in 8.3.1, for which the following agreement was made during RAN1 #106-e.   |  | | --- | | **Agreement**  In addition to HARQ-Ack of PDSCH dynamically scheduled by a DCI indicating a PUCCH carrier, the dynamic target carrier indication also applies to:   * HARQ-ACK corresponding to the first SPS PDSCH activated by Activation DCI based on the indication in the activation DCI * HARQ-ACK corresponding to the SPS Release DCI based on the indication in the release DCI * triggered PUCCH for Rel-16 Type 3 CB, Rel-17 enh. Type 3 CB of smaller size and Rel-17 one-shot triggering for HARQ-Ack retransmission based on the indication in the triggering DCI * FFS: Additional cases |   Therefore, for the sake of consistency with both specification and common understanding in RAN1, we prefer the formulation provided by FL proposed conclusion 0, as provided by FL during #106b-e. |
| CATT | We support to have a conclusion.  For the FFS, it is worth to mention that *Issue#23* of *AI 7.1* in THIS meeting is about clarification for the first SPS PDSCH in 38.214. According to the feedback from companies, it seems to be a common understanding that that the first SPS PDSCH associated with the activation DCI is viewed as a dynamic scheduled PDSCH repetition.  Following the same logic, we tend to agree that dynamic PUCCH repetition factor indication mechanism is applied to HARQ-ACK for the first SPS PDSCH. |
| Vivo | Support.  In our understanding, the HARQ-ACK resource for first SPS PDSCH associated with the activation DCI is also indicated by PRI, hence dynamic PUCCH repetition factor should be applied. |
| ZTE | Support.  As CATT pointed out, it is a common understanding that the first SPS PDSCH associated with the activation DCI is treated as a dynamic scheduled PDSCH repetition based on the discussion in AI 7.1. So, we support dynamic PUCCH repetition factor indication is also applied to HARQ-ACK for the first SPS PDSCH associated with the activation DCI. |
| Intel | We do not support this conclusion.  As mentioned previously, our understanding is that based on the agreement, it is clear that if a PUCCH is associated with a scheduling DCI, dynamic PUCCH repetition factor indication is supported. This covers the cases for 1) dynamic HARQ-ACK feedback 2) HARQ-ACK feedback for HARQ-ACK for the first SPS PDSCH associated with the activation DCI, 3) HARQ-ACK corresponding to the SPS Release DCI.  Further, we also need to cover other cases, e.g., when PUCCH carrying dynamic HARQ-ACK overlaps with PUCCH resource carrying other UCI types like P-CSI, SR, etc.. In this case, dynamic repetition factor indication is applied for the determined PUCCH resource which is associated with a DCI based on the agreement.  In our view, we can either list all possible cases, or only state the following as conclusion or proposal.   * Dynamic PUCCH repetition factor indication for HARQ-ACK of SPS PDSCH which is not associated with or activated by a DCI is not supported. |
| Apple | We share similar view as Nokia/NSB |
| Ericsson | We are OK with the main bullet.  However, we seem to have an opposite understanding from vivo, CATT, and ZTE on if there is an SPS PDSCH scheduled by the activation DCI. Our understanding is that an SPS activation DCI does not schedule a PDSCH, but only activates it. So the configured PUCCH resources used for all PDSCHs scheduled by SPS are configured PUCCH resources.  Since this is Rel-15 behavior, we prefer to be very conservative in the FFS. As the FFS is written now it assumes there is a PDSCH (and a HARQ-ACK) for the activation DCI. Can we have something like:  **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.** |
| Lenovo, Motorola Mobility | Support the conclusion.  For the FFS, we agree with Panasonic that Rel-15/16 specification should be applied to determine whether the HARQ-ACK associated with first SPS PDSCH is considered as dynamic or semi-static PUCCH |

## Other proposals

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

R1-2111694 Proposal 1: RAN1 should specify whether later DCI can override former DCI indicating the same PUCCH slot with different PUCCH repetition factor.

R1-2111890, Proposal 6: Support the existing mechanism in 38.213 Sec. 9.2.3 when number of resources per PUCCH resource set is up to 32.

* Combine existing mechanisms based on PRI, NCCE and nCCE,0 to indicate the PUCCH resource with repetition factor within a PUCCH resource set up to 64 PUCCH resources

R1-2112233 Proposal 1: Support also using other properties of PDCCH (e.g. PDCCH aggregation level), in addition to PRI and starting CCE index, to indicate the PUCCH resource.

R1-2112233, Proposal 3: Support enhancing RRC signaling to allow dynamic indication of frequency hopping for PUCCH repetition via indication of PUCCH resource.

R1-2111981, Proposal 1: The following methods to configure PUCCH repetition for the UE without dedicated PUCCH resource configuration should be studied.

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

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** |
| Panasonic | We are supportive to R1-2112233, Proposal 3. If the length of configured TDW and/or hopping interval is per PUCCH resource, in addition to PUCCH repetition factor indication, length of the configured TDW and/or hopping interval can be indicated as an additional parameter in the PUCCH resource set and PUCCH resource indicator field can be reused. In this case, in order to allow flexibility, extending the PUCCH resource indicator field would be one possibility. |
| Apple | For R1-2111890, Proposal 6, it should be discussed whether number of PUCCH resources within a set is allowed be larger than 32 or not. And if so, what will be the new formulation to map (PRI, NCCE and nCCE,0) to indicate the PUCCH resource (based on the existing agreement). |
| Ericsson | Agree with FL summary in general. Most proposals seem to be further optimization/flexibility that may not be so essential.  For R1-2111694, we are open to further discussion, but wonder why indicating two different repetition values for the same PUCCH slots is not an error case. |
|  |  |

# DMRS bundling across PUCCH repetitions

The second objective of this agenda item is to “specify mechanism to support DMRS bundling across PUCCH repetitions.” Under this objective, a few topics are addressed in companies’ contributions. The topics are summarized as below.

## Use cases

Regarding the use cases for DMRS bundling for PUSCH repetitions, the following conclusion was made in RAN1 106bis in AI 8.8.1.3.

**Conclusion**

* Joint channel estimation over PUSCH transmissions across non-consecutive slots is not supported in Rel-17.

For the use cases of DMRS bundling for PUCCH repetitions, companies’ input are listed as below.

R1-2111432 Proposal 1: Not support Use case 5 for PUCCH repetitions with DMRS bundling.

R1-2112233 Proposal 4: RAN1 to confirm that use cases 3 and 4a are the only two use cases for PUCCH DMRS bundling.

R1-2110866 Proposal 8. For non-back-to-back PUCCH transmissions, in case the other UL transmission in between two successive PUCCH repetitions has different settings than PUCCH, the gNB indicates one of the following options to the UE:

* Option 1: Drop the other UL transmission with different settings.
* Option 2: Transmit the other UL transmission with different settings and break the phase continuity.
* Option 3: Adapt the settings of the other UL transmission to make it be the same as the PUCCH repetitions.

Given that RAN1 should strive for a common design between PUCCH and PUSCH DMRS bundling, it is reasonable to make the following conclusion for PUCCH as well.

**FL proposed conclusion 2: The following use case 5 of PUCCH DMRS bundling is not supported in Rel-17**

* **Use case 5: PUCCH repetitions across non-consecutive slots.**
  + **Use case 5a: no uplink transmission in the middle of two PUCCH repetitions**
  + **Use case 5b: other uplink transmissions in the middle of two PUCCH repetitions**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | OK |
| Panasonic | We are fine with the FL proposed conclusion 2. |
| QC | Support |
| Nokia/NSB | Ok |
| China Telecom | We support this proposal. |
| CATT | Agree. |
| Vivo | Support. |
| ZTE | Support |
| CMCC | Support FL proposal conclusion 2. |
| Intel | We are fine with the conclusion. |
| Apple | Support |
| Ericsson | Support |
| Lenovo, Motorola Mobility | Support the conclusion |

## PUCCH TDW design details

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

**Working assumption:**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

* An event occurs that violates power consistency and phase continuity

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

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

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

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

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

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

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

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

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

Furthermore, the following agreements were made in RAN1 106bis on TDW design.

**Agreement**

* For PUSCH repetition type A counting based on physical slots
  + The configured TDWs are consecutive, where the start of other configured TDWs is the first physical slot right after the last physical slot of a previous configured TDW.
* For PUSCH repetition type A counting based on available slots
  + The configured TDWs are determined based on available slots, where start of a configured TDWs is the ~~next~~ first available slot after the ~~conclusion~~ last available slot of a previous configured TDW.
  + Note: The determination of available slots for PUSCH repetition Type A is defined in AI 8.8.1.1.

Working Assumption

Support Actual TDW Option 2b’:

* The start of the first actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the first PUSCH transmission in an available slot within the configured TDW.
* The end of the actual TDW is
  + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the last PUSCH transmission in an available slot within the configured TDW if the actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
  + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ of the PUSCH transmission right before the event if an event occurs that violates power consistency and phase continuity, and the PUSCH transmission is in an available slot.
  + For UE capable of restarting DM-RS bundling, the start of the new actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for PUSCH transmission after the event violates power consistency and phase continuity, and the PUSCH transmission is in an available slot.

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

**FL Proposal 2: For PUCCH DMRS bundling, when appliable, reuse the procedure developed for PUSCH DMRS bundling to determine configured TDW(s) and actual TDW(s).**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | OK and the procedure of the configured TDW determination for PUSCH repetition type A counting based on available slot should be reused for PUCCH’s configured TDW determination. |
| Panasonic | We are fine with FL proposal 2. |
| QC | Support |
| Nokia/NSB | Support |
| China Telecom | We support this proposal. |
| CATT | Support. |
| vivo | Support. |
| ZTE | Support |
| CMCC | Support. |
| InterDigital | Support |
| Intel | We are fine with the FL proposal.  Our understanding is that the agreement for determination of configured TDWs for PUCCH repetition for FDD/TDD system was already captured in 214. |
| Ericsson | OK in principle, but e.g. TDRA table is not used for PUCCH. Also, we have not discussed events for PUCCH; should we have ‘FFS: events for PUCCH’? |
| Lenovo, Motorola Mobility | Support the proposal |

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 106bis, the following agreement is made.

**Agreement:**

**For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, a UE perform the “hopping intervals determination”, “configured TDW determination”, and “actual TDW determination” in a sequential ordering. One option of the following options is to be selected.**

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

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

Based on companies input in Tdocs submitted to RAN1#107, the pros and cons of the above options are summarized as below.

|  |  |
| --- | --- |
| Option 1: | Pros: more efficient resource allocation for MU, including Rel-15/16 UEs not supporting DMRS bundling and Rel-17 UEs with different length of configured TDW [R1-2112233, R1-2112038] |
| Cons: smaller DMRS bundling gain, when hopping interval and configured TDW having misaligned length [R1-2110792] |
| Option 2: | Pros: Better DMRS bundling performance over option 1 [R1-2111439, R1-2112122] |
| Cons: less efficient resource allocation for MU [R1-2112233, R1-2112038] |
| Option 4: | Pros: higher gain for the combination of joint channel estimation and frequency hopping [R1-2110866, R1-2112122]; Guaranteed same length between actual TDW and hopping interval [R12111951]. |
| Cons: dynamic events impact hopping pattern [R1-2111439], mis-alignment of hopping pattern between gNB and UE, due to missed DCI [R1-2111510] |

The positions of companies are summarized in below:

* Supporting option 1: ZTE, Spreadtrum, CATT, Intel, XiaoMi, Samsung, Interdigital, Apple, Sharp, Ericsson, QC
* Supporting option 2: Huawei/HiSi, ZTE, VIVO, Panasonic, Sharp, DCM
* Supporting option 4: Nokia, CMCC, Lenovo, ETRI, Wilus

FL’s assessment is that the missing DCI is indeed an issue for option 4. Between option 1 and option 2, they have pros and cons over each other, depends on the design criteria is optimizing SU performance or MU performance. Also considering the number of companies supporting each option, FL recommend to take option 1. Therefore, the following proposal is made.

**FL Proposal 3: For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, option 1 (as agreed in RAN1 106bis) is adopted.**

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

|  |  |
| --- | --- |
| **Company name** | **Comment** |
| Sharp | Support |
| Panasonic | We agree to FL’s assessment that the missing DCI is the issue for Option 4. On comparison between Option 1 and Option 2, Option 2 can achieve “frequency positions are alternatives in every configured TDWs” and such frequency hopping pattern can provide better performance than Option 1. For TDD, if only 2 or 4 slots is considered for the length of frequency hopping interval, such length is not so aligned with TDD configuration. In this case, we think Option 1 results in poor frequency hopping performance. In order to achieve the similar hopping pattern as Option 2, we can compromise to Option 1 with the configuration that hopping interval and configured TDW are same as the period of TDD {DL + S + UL} slots. That means 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}. |
| QC | Support |
| Nokia/NSB | We think that this deserves a bit more discussion, given that we have never discussed how each Option would be realized in practice. Before doing this, we would like to elaborate on major differences between Option 1 and the others. We believe that this is fundamental to ensure that RAN1 does not make a hasty decision which may undermine the success of the feature:   * Option 2 and Option 4 imply that FH patterns/intervals for DM-RS bundling are implicitly defined and configured once the nominal TDW is configured to the UE (for Option 2) and once actual TDW is determined (for Option 4). Conversely, such patterns will have to configured separately to each UE in Option 1. It is worth observing that RAN1 has not started discussing about new patterns/intervals yet and this is the last meeting of the release. If we do not agree on such new patterns/intervals, then Option 1 is fundamentally incompatible with DM-RS bunding due to how current hopping patterns/intervals work for PUSCH (based on odd/even slot number within radio frame) or PUCCH (based on odd/even slot number within sequence of N PUCCH repetitions). In this context, we are not comfortable with the idea of rushing the design of this aspect now, or signing a blank cheque, with no possibility to have a proper technical discussion about it. Furthermore, it is also worth adding that this would complicate the signaling anyway, regardless of which FH patterns/interval might be agreed. * The missing DCI problem impacts Option 4 only in case of dynamic events, but not in case of semi-static events. * Option 4 is a generalization of Option 2, which offers more flexibility in combining FH and DM-RS bundling gain. * We think that the advantages for MU scheduling of Option 1 are overrated, unless we are implying that DM-RS feature is never enabled. Assuming the existence of new FH patterns/intervals (which do not exist yet), Option 1 would simplify the MU scheduling of CE UEs for which DM-RS bundling is activated, and configured TDW length is identical across such UEs. However, it would not offer any advantage in all other cases, since the hopping patterns/intervals of legacy UEs, of CE UEs for which DM-RS bundling is not activated will be the same as for R15/R16. In this sense, Option 1 would offer advantages only when a very minor set of UEs in the cell are scheduled in the same slot(s). We argue this is a corner case and we would like to understand why proponents of Option 1 consider it so important.   Now, moving to how different Options could work:   * Option 1:   + It requires new FH patterns/intervals to be designed (and we haven’t started this yet)   + It requires FH patterns/intervals and TDW to be configured to the UE separately   + It handles semi-static and dynamic events in the same way.   + Performance depends on how flexible the configuration of the new FH patterns/intervals is. * Option 2:   + It does not require new FH patterns/intervals to be designed, since the duration of each hop is equal to the size of the nominal TDW   + It does not require FH patterns/intervals and TDW to be configured separately   + It handles semi-static and dynamic events in the same way. * Option 4:   + It does not require new FH patterns/intervals to be designed, since the duration of each hop is equal to the size of the corresponding actual TDW   + It does not require FH patterns/intervals and TDW to be configured separately   + It can handle semi-static and dynamic events in the same or different ways.   Given the above, we observe that Option 4 is the most flexible and powerful option, whose performance does no rely on assumptions on how FH patterns/internals are designed and configured. The problem of the missing DCI can be solved easily by handling semi-static and dynamic events separately as follows:   * If an actual TDW is created due to a semi-static event, UE hops.   + The length of FH intervals and nominal TDW can be different, depending whether semi-static events occur within the TDW or not. * If an actual TDW is created due to a dynamic event, UE does not hop.   + The length of FH intervals and nominal TDW is the same.   In other words, FH across actual TDWs could occur in Option 4 in case of semi-static events (the missing DCI is not a problem) where it cannot occur in case of dynamic events. This would make Option 4 behave like Option 2 in case of dynamic events.  We think this would be the best compromise to account for all companies’ preferences, while (i) simplifying the discussion on FH, and (ii) not hindering the success of the feature. |
| China Telecom. | We support Option 1, but we want to make some more clarification on option 1. For option 1, the hopping interval can be separately configured and can be different from the window length of the **configured TDWs** and **the actual TDWs**. In this option, inter-slot frequency hopping with inter-slot bundling can be deemed as one semi-static event that violates the power consistency and phase continuity. |
| CATT | We support the proposal. Option 1 will be more compatible for cell-level UE multiplexing.  In addition, if the hopping interval is configured as equal to the window length of the configured TWDs to obtain the best performance of JCE (without the breaking of power consistency and phase continuity caused by frequency hopping), there seems no much difference between option 1 and option . |
| Vivo | Not support this proposal, and prefer option 2.  It has been agreed in AI 8.8.1.1 that no new inter-slot frequency hopping mechanism is introduced for PUSCH repetition type A without joint channel estimation. If frequency hopping interval is configured by a separated RRC parameter, a new hopping pattern can be introduced when DMRS bundling is not enabled, which would violate previous agreements.  Besides, configuring frequency hopping interval and configured window separately is obvious deviation from the intention of inter-slot frequency hopping with DMRS bundling. Hence, opt-1 is not preferred. |
| ZTE | In our view, we need to first clarify some fundamental questions about FH, including,   1. Whether the FH interval is RRC configured or not? 2. Whether the FH interval it is the same as configured TDW or it is a new RRC parameter that is separately configured? 3. Whether FH is an event or not?   For 1), our answer is yes. One value for FH configured by RRC is sufficient, and there is no need multiple values or dynamic indication.  For 2), we slightly prefer to use the same length for configured TDW and FH interval.  For 3), if FH interval is the same as configured TDW, FH is not an event. Otherwise, we need to treat it as an event.  In addition, it needs to clarify the main difference between Option 1 and Option 2. If the options only presents a proceeding order without any clear restrictions between FH intervals and configured TDW, we don’t see much difference between the two options. |
| CMCC | We cannot agree with the proposal and still support option 4. As we are talking about the determination of actual TDW and frequency hopping TDW, both of them should be determined based on the configured TDW and the semi-static event, e.g. TDD-UL-DL configuration, before the transmissions and frequency hopping. Then the frequency hopping interval is determined. If an dynamic event happens before the determination, it should be also considered for the determination but it also happens before the transmission. Then when the PUSCH/PUCCH transmission happens, the frequency hopping interval is determined. And once the dynamic event happens during the transmission, a new actual window is generated and the DMRS bundling is also interrupted but the frequency interval will not change. We cannot change the frequency hopping pattern while we are doing it. This is the same case as option 1 and 2, in which the frequency hopping interval are not changed dynamically.  For the dynamic event, the DMRS bundling of all three options will be interrupted. But the benefit of the option 4 is, for some predictable dynamic event or the dynamic events that are already known, the frequency hopping pattern could fit into it and does not lose the JCE gains.  And for the miss detection of DCI, if it happens during the transmission, it is same for the three cases. The DMRS bundling are not interrupted and the frequency hopping does not change.  For option 1, the performance will depends on the proper configuration of both frequency hopping interval and the configured TDW. |
| InterDigital | Support |
| Intel | We support the FL proposal.  For Option 4, this may have mis-alignment between gNB and UE side, when considering the potential mis-detection of dynamic events. This would result in PUSCH decoding failure if hopping boundary is not aligned between gNB and UE side.  Further, in Rel-15/16, inter-slot frequency hopping pattern is defined based on slot index. Option 1 can help to allow backward compatibility. If hopping interval is configured with different value from the TDW length, this can provide appropriate tradeoff between frequency diversity gain and channel estimation gain |
| Apple | Support FL’s proposal |
| Ericsson | We support option 1.  Regarding agreements in 8.8.1.1: our understanding is that agreement addressed FH proposals specific to Type A repetition. We here discuss FH in support of JCE. Then, as usual, if the mechanism should be precluded for certain scenarios can be discussed.  As we show in R1-2112037, there are tradeoffs of diversity gain vs. channel estimation gain, so restricting a hopping pattern to be a function only of a TDW size could degrade the performance of hopping.  Similarly, different UEs in a cell could support different maximum durations or not support DMRS bundling, while on the other hand UEs should be able to share a hopping pattern in order to avoid wasted PUSCH resources. If the hopping patterns are different according to scheduling or if we are forced to configure different patterns to match bundling capability, the capacity gains from hopping will be degraded by less resource efficiency.  Lastly, as we have discovered during the WI phase, maintaining phase coherence is often not feasible, and so JCE mechanisms are in general rather more difficult to implement in a UE than frequency hopping. Exploiting FH gains as part of a mechanism designed to support JCE is therefore quite important, and should be available to both UEs that do and do not support JCE.  Regarding the design of the mechanism itself, we think a simple one can be straightforward and could use the following principles:   * The hopping offsets are determined by the slot index * Frequency hopping is an event that sets the actual TDW size * UEs can be configured with the hopping pattern * Support increased numbers (e.g. up to 4) of hopping offsets, where the number of consecutive slots per hop can be controlled. |
| Lenovo, Motorola Mobility | We don’t support the proposal and agree with Nokia to have further discussion on this. In our view, option 4 is simpler, yet flexible option and doesn’t require further discussion on hopping patterns as they are implicitly determined by the actual window duration. With option 2 also, similar conclusion can be made, so we would be okay to support option 2 as our second preference.  However, option 1 would require separate configuration and design of hopping patterns |

On inter-slot frequency hopping, there are proposals from companies to address the issue whether the same or different length should be applied to hopping interval and TDWs.

R1-2111430 Proposal 2:

* For inter-slot frequency hopping with inter-slot bundling, the hopping interval is separately configured and can be different from the window length of the configured TDWs and the actual TDWs.
* The hopping interval can be configured smaller than the window length of the configured TDWs. Whether the hopping interval can be configured larger than the window length of the configured TDWs needs further study.

R1-2111510 Proposal 3

* For inter-slot frequency hopping with inter-slot bundling
  + Option 1 is supported for the hopping interval determination.
  + Hopping interval can be separately configured from TDW length.
  + Frequency hopping pattern is determined based on slot index.

R1-2112022 Proposal 2: The length of the configured TDW (i.e., the window length L) should be equal to the hopping interval by configuring single parameter.

R1-2112122 Proposal 3: Configured time domain window length (L) should be used for the determination of hop duration in inter-lost frequency hopping.

R1-2111439 Proposal 6: For PUSCH/PUCCH with joint channel estimation, the inter-slot frequency hopping is performed per configured TDW, which is determined based on configured/indicated TDW length and semi-static TDD configuration.

On this issue, FL would like to collect more views from companies using the following table, before making a proposal.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company name** | **Support same or different length between hopping interval and configured TDW?** | **Pros and cons of adopting same length** | **Pros and cons of allowing different length** |
| Sharp | Support same length between hopping interval and configured TDW. | Pros: The occurred number of events within the configured TDW can be reduced and error propagation can be mitigated. |  |
| Panasonic | Support same and different length | Pros: Better gain due to both the frequency hopping and joint channel estimation  Cons: Since maximum duration for configured TDW could be UE capability, common hopping pattern among UEs could not be possible. | Pros: Common hopping pattern among UEs is possible.  Cons: Less frequency hopping and/or joint channel estimation gain |
| QC | Support different lengths |  | We are thinking of hopping being completely decoupled from TDW configuration. Therefore aligning with TDW configurations may not even be possible. Hopping patterns may be common across a cell, while TDW config may be UE specific. |
| Nokia/NSB | Different length in case of actual windows created by semi-static events  Same length in case of actual windows created by dynamic events.  Therefore, we support a mixed approach, as explained in the previous table. | PRO: If only one actual window exists inside the nominal window, i.e., no event occurs, adopting the same length guarantees max performance of DM-RS bundling.  CON:   * If events occur within a nominal window, i.e., two or more actual TDWs are created, then the advantage in terms of DM-RS bundling may vanish * FH gains will be smaller, regardless of whether events occur within a TDW or not | PRO: FH gains are larger, irrespective of whether events occur or not  CON: The advantage in terms of DM-RS bundling may vanish, if Option 1 is adopted. |
| China Telecom | We support different length between hopping interval and configured TDW.  Assuming the length of hopping interval is *M* and the length of configured TDW is *L*.  We think *M* should be less than or equal to *L*. Moreover, *L* and *M* can have the following relationship as *L* = *k·M*, where *k* is a positive integer. | Pros: Since the window length of the configured TDWs is explicitly configured, gNB and UE have the same understanding where frequency hopping takes place.  Cons: less flexibility. | Pros: gNB has the flexibility to configure the appropriate hopping interval taking into account both gain of frequency hopping and gain of joint channel estimation. |
| CATT | We support different length between hopping interval and configured TDW. | Cons: If the length of the configured TDW is large and the channel condition in one hop is terrible, JCE cannot compensate for the loss of diversity gain. | Pros: More configuration flexibility. Separate configuration for frequency interval and window length of the configured TDW does not mean that two parameters always need to be different. |
| vivo | Same | Pros:  simple, and better performance due to phase continuity are not violated in a configured TDW due to FH. | Cons:  1, higher signaling overhead to configure a different length;  2, If hopping interval is different than configured TDW, it may lead to degraded performance, due to shortened actual TDW; |
| ZTE | Same | Pros:  Less signaling overhead; simple procedure without considering FH as an event; and better performance by DMRS bundling across a longer duration. | Cons:  Large signaling overhead; FH needs to be treated as an event which unnecessarily complicates the implementation; Worse performance. |
| InterDigital | Same | Pro : consistency, for the same reason mentioned by China Telecom |  |
| Intel | Same or different lengths for hopping interval and configured TDW. | Pro: no need to signal the hopping length parameter.  Con: this may depend on maximum duration that UE can support for DMRS bundling. | Pros: can achieve appropriate tradeoff between channel estimation gain and frequency diversity gain.  Can provide good flexibility on the gNB scheduling and resource allocation in the network. |
| Ericsson | Support different length, but also same length depending on configuration | Cons:  Forces UE specific hopping patterns, since the CTDW determines the hopping, making it hard to get good resource efficiency.  The DDDSUDDSUU TDD pattern may have imbalanced hopping (see R1-2112037)  Unnecessarily restricts FH to exactly match JCE. | Pros:  Allows cell specific FH operation, where UEs can hop in the same pattern to improve resource efficiency.  Allows more tradeoffs of diversity vs. channel estimation gain. |
| Lenovo, Motorola Mobility | In our view, it is more crucial to have the same length between actual TDW and hopping interval. The configured TDW may be same or different length | Pros: Same length between actual TDW and hopping interval will ensure maximum performance gain from JCE |  |

## Other proposals

R1-2111030 Proposal 3: DMRS bundling size of L = 1 slot may need to be introduced, if DMRS bundling for sub-slot PUCCH repetitions within a slot is supported.

R1-2111030 Proposal 5: The starting RB for each frequency hop is determined by frequency hop index, and the frequency hopping index corresponds to the order of configured TDWs for PUCCH/PUSCH repetitions.

R1-2112038 Proposal 6:

* Enhanced frequency hopping designs for PUCCH supporting joint channel estimation support increased numbers (e.g. up to 4) of hopping offsets, where the number of consecutive slots per hop can be controlled.

R1-2111030 Proposal 3: UCI repetition with DM-RS bundling can prioritize with respect to its UCI type (of a same priority index).

R1-2111030 Proposal 2: If inter-slot frequency hopping is enabled, then the PUCCH repetition may hop in the middle of slot, depending on the TDD slot pattern and the number of repetitions, and the coherence can be kept in the same split.

R1-2111439 Proposal 4: If the length of the configured TDW needs dynamic indication, PUCCH resource indicator field can be used to inform UE length of the configured TDW. If dynamic indication is supported, consider extending PUCCH resource indicator field for further flexibility.

R1-2111890 Proposal 2: 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.

R1-2111981 Proposal 3: For the time domain window for DMRS bundling of PUCCH, adopt a time domain window based on available slots for joint channel estimation of PUSCH.

R1-2112038 Proposal 3:

* Enhanced frequency hopping designs for PUCCH supporting joint channel estimation include the following:
  + The hopping offsets are determined by the slot index
  + Frequency hopping is an event that sets the actual TDW size
  + UEs can be configured with the hopping pattern

R1-2111274 Proposal 2: UE performs the inter-slot frequency hopping with inter-slot bundling as long as the hopping interval of inter-slot bundling is configured.

R1-2110866 Proposal 5. RAN1 to discuss and define hopping intervals longer than 1 slot

FFS: details for definition of hopping intervals

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** |
| vivo | Sub-slot based PUCCH repetition have been introduced in URLLC, and PUCCH repetitions can be transmitted within a slot. If joint channel estimation can be enabled for sub-slot PUCCH repetitions, the DMRS bundling size can be 1 slot.  We may need to further discuss whether this use cases are supported, especially is ‘PUCCH-DMRS-bundling’ is configured per BWP. |
|  |  |

# 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

|  |  |  |
| --- | --- | --- |
| [R1-2110792](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110792.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2110866](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110866.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |
| [R1-2110921](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2110921.zip) | Discussion on coverage enhancements for PUCCH | ZTE |
| [R1-2111030](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111030.zip) | Remaining issues on PUCCH enhancements | vivo |
| [R1-2111109](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111109.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2111274](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111274.zip) | Discussion on PUCCH enhancement | CATT |
| [R1-2111331](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111331.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2111430](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111430.zip) | Remaining issues on PUCCH enhancements | China Telecom |
| [R1-2111439](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111439.zip) | Discussion on PUCCH enhancement for NR coverage enhancement | Panasonic Corporation |
| [R1-2111510](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111510.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2111587](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111587.zip) | Discussion on PUCCH enhancements | Xiaomi |
| [R1-2111623](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111623.zip) | Discussion on PUCCH enhancements | CMCC |
| [R1-2111694](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111694.zip) | Discussion on dynamic PUCCH repetition factor | NEC |
| [R1-2111754](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111754.zip) | PUCCH enhancements | Samsung |
| [R1-2111795](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111795.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2111890](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111890.zip) | PUCCH coverage enhancement | Apple |
| [R1-2111951](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111951.zip) | Enhancements for PUCCH repetition | Lenovo, Motorola Mobility |
| [R1-2111981](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111981.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2111993](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2111993.zip) | PUCCH enhancements | ETRI |
| [R1-2112022](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112022.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2112038](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112038.zip) | Remaining Issues for PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [R1-2112122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112122.zip) | PUCCH enhancements for coverage enhancement | NTT DOCOMO, INC. |
| [R1-2112233](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112233.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2112392](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_107-e/Docs/R1-2112392.zip) | Discussion on PUCCH enhancements for coverage enhancement | WILUS Inc. |