**3GPP TSG RAN WG1 #105-e R1-210xxxx**

**e-Meeting, May 10th – 27th, 2021**

**Agenda item:** 8.8.2

**Source:** Moderator (Qualcomm)

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

**Document for:** Discussion/Decision

# Introduction

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

# Dynamic PUCCH repetition factor indication

## Scope of dynamic PUCCH repetition factor indication

Regarding whether dynamic PUCCH repetition factor indication should be applied to semi-static PUCCH, there are diverged views based on submitted contribution from companies.

Spreadtrum, QC, ETRI, and Ericsson support dynamic PUCCH repetition factor indication to P/SP PUCCH as well. On the other hand, CATT and LG don’t support dynamic PUCCH repetition factor indication for P/SP PUCCH.

**FL Question: Whether dynamical PUCCH repetition factor indication should be applied to semi-static PUCCH?**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Samsung | No – there is no payload variation and there is no variation in the PUCCH resource. Rel-16 works fine for semi-static PUCCH. |

**FL Question: How to indicate repetition factor for semi-static PUCCH dynamically. Are there other proposals besides the following?**

* **Option 1: implicitly indicated based on configuration of PUCCH resource set for each PUCCH**
* **Option 2: indicated by switching of associated PUCCH resource sets (e.g. for SPS PUCCH or PUCCH carrying CSI)**
* **Option 3: implicitly indicated based on the dynamic indication via PDCCH**
* **Option 4: indicated via activation/reactivation DCI**

The description of each of above options is not very clear in the contributions. Proponents of those options please provide clarification in the following table to clarify each of the proposals. In addition, companies are welcome to propose new options if any in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Samsung | No need to dynamically indicate the repetition factor for semi-static PUCCH |

## Options for dynamic PUCCH repetition factor indication

In RAN1 104-e meeting, the following agreements were made regarding dynamic PUCCH repetition factor indication.

Agreements: Down select from the following two options to support dynamic PUCCH repetition factor indication.

* Option 1 (without DCI enhancement): Enhance RRC signaling to allow configuration of PUCCH repetition factor per PUCCH resource. PUCCH repetition factor is implicitly indicated by DCI.
	+ FFS details, e.g., via reusing the “PUCCH resource indicator” field (without increase # bits of it), starting CCE index (when applicable) of DCI, by PDCCH aggregation level, etc.
	+ FFS: RRC signaling enhancement details
* Option 2 (with DCI enhancement): PUCCH repetition factor is explicitly indicated by DCI
	+ e.g., introduce a new field or increase the number of bits of an existing field (e.g., PRI) in DCI for PUCCH repetition factor indication
	+ FFS whether there is a need for RRC update

Based on companies’ contribution, the pros and cons of the three options can be summarized in the below table.

|  |  |  |
| --- | --- | --- |
|  | Pros | Cons |
| Option 1 | Minimum spec change (only has RRC change. NO DCI change)**Applicable to fallback DCI** | Less flexibility  |
| Option 2 | Maximal flexibilityLarger spec impact (Need DCI change. May need RRC change depends on detailed solution of option 2) | Increased DCI size/new DCI field**Not applicable to fallback DCI** |

According to companies’ contributions, the split of supporting companies for option 1 and option 2 are as follows.

* 20 Companies supporting option 1: Huawei/HiSi, VIVO, CT (2nd preference), CATT (1st preference), CMCC(1st preference), IDC, Intel, Apple, Panasonic, Spreadtrum, ETRI, Xiaomi, Sharp, Ericsson, Docomo, Lenovo/Moto, LG?, ZTE
* 9 companies supporting option 2: ZTE, OPPO, CT (1st preference), Samsung, CATT (2nd preference), CMCC (2nd preference), Nokia/NSB, LG?

Both options can work to support dynamic PUCCH repetition indication. Considering that option 2 cannot be used with fallback DCI, which is typical used DCI for coverage limited UE, from technical point of view, option 1 seems better. Furthermore, majority companies support option 1. Therefore, FL recommend the group to take option 1 to move forward.

**FL Proposal 1: Option 1 (as agreed in RAN1 104-e) is adopted to support dynamic PUCCH repetition factor indication.**

* **[FFS: if the PRI field size can be expanded]**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| CATT | Support. |
| ZTE | Support.We’d like to clarify our position as indicated in our tdoc. We support Option 1, and also fine with Option 2 with enhancing the PRI bit filed on top of Option 1.  |
| Nokia/NSB | According to TR 38.830, coverage difference between PDCCH and PUCCH is quite significant, in favor of the former. Remarkably, a 40-bit payload was assumed during the SI, which is compatible with non-fallback DCI format payload sizes. This seems to indicate that typical use case of fallback DCI may not be for coverage shortage situations, but rather for configuring a UE in a capability-agnostic way. Of course, smaller DCI payloads could offer larger coverage. However, since PDCCH coverage as such is not a problem, it does not seem meaningful to focus on it to decide which Option should be retained. In our view, for instance, potential limitations of Option 1 for the flexibility of the PDCCH scheduling operations at gNB are source of larger concerns, given that what is currently possible for indicating PUCCH resources belonging to PUCCH resource set with ID 0 (which can already be configured with up to 32 PUCCH resources) would be extended to PUCCH resource sets with ID>0. This would force gNB to consider a much larger set of constraints and limitations while scheduling PDDCH, since specific choices could imply potential indications UE would consider for PUCCH resource selection. In this sense, limiting this number of possibilities seems wiser from implementation perspective, especially if we consider that DCI-base alternatives exist can be adopted with much smaller impact on gNB’s scheduler, with arguably negligible impact on the coverage of PDCCH (which again has been concluded not to be a problem during the SI).  |
| China Telecom | Support. |
| Intel | We are fine with the proposal. |
| Ericsson | **Fine with the spirit of the proposal, but prefer the following FFSs on top of Option 1.** Allowing for UL in addition to DL grants and/or a larger field size may help with companies concerned about scheduler flexibility. (More on this first point below)* FFS: DCI 0\_1 enhancement for P/SP-CSI
* FFS: if the PRI field size can be expanded.

**We think it is fundamental for this feature that DCI is able to be used to control P/SP-CSI repetition.** Because CSI was identified as the tightest bottleneck for PUCCH in the SI, PUCCH repetition enhancement should be motivated primarily by CSI. Unfortunately, PUCCH repetition that carries CSI and whose resource is indicated by DCI is not supported today. While we’d like to see this fixed, this means that periodic & semi-persistent CSI is a more natural starting point for dynamic PUCCH repetition carrying CSI. DCI could control P/SP-CSI repetition in either UL or DL grants. If a DL grant is used, we think this could be done with Option 1. However, a UL grant would require new information in DCI, and so Option 2 would be needed in that case. While we think this is not a crucial feature to have, and should be in addition to a DL grant based solution, it could provide additional scheduler flexibility (e.g. when there is not DL data for the UE). So then instead of a completely different option, we would prefer to extend Option 1 specifically for the P/SP-CSI case. |
| Lenovo, Motorola Mobility | We support the FL proposal  |
| Apple | Support the proposal |
| Sharp | We support the FL proposal. |
| vivo | Support the proposal |
| NTT DOCOMO | We support the FL proposal. |
| InterDigital | We support the proposal from the FL. |
| CMCC | Support the proposal. |
| Panasonic | We are fine with the proposal in principle, i.e., for dynamic PUCCH repetition factor indication, enhance RRC signaling to allow configuration of PUCCH repetition factor per PUCCH resource. PUCCH repetition factor is indicated via reusing PUCCH resource indicator field. However, we prefer to add the following FFS on top of Option 1.FFS: If the PRI field size can be expandedThe reason of above FFS is following. In addition to PUCCH repetition factor indication, enabling or disabling DMRS bundling and the length of time domain window might be indicated as an additional parameter in the PUCCH resource set and PUCCH resource indicator field can be reused. In order to allow the flexibility, we would like to add FFS on the extension of PUCCH resource indicator field. |
| Qualcomm | Support the proposal |
| Samsung | Before agreeing to Option 1 we would like to understand how different number of repetitions can be supported for different UCI payloads that use a same PUCCH resource (assuming that the PUCCH resource indication flexibility is not be compromised compared to Alt. 2). Also, while Alt. 2 is simple and clearly defined, there are many variants under Option 1 (bundled under an “FFS details”). We need to know what Option 1 is if we are to agree to it.Regarding the fallback DCI for Alt.2, there is no issue. The situation is same as for any other optional field (e.g. beta\_offset) – RRC configuration is used and that is enough for fallback.   |
| FL | It seems majority companies are fine with option 1. To Ericsson and Panasonic: the formulation/split between option 1 and 2 is that, option 1 has no DCI enhancement needed, while option 2 needs DCI enhancement. If adding the FFS on expand PRI field under option 1. Then it is option 2. I am not sure all the companies supporting option 1 can accept this. To Samsung: I hope the proponents of option 1 can answer your question. I can also share my personal opinion as FL from technical point of view. I think to address the question “different number of repetitions can be supported for different UCI payloads that use a same PUCCH resource” – gNB will need to duplicate the same PUCCH resource multiple times, each with different repetition number. Then use PRI to pick one resource with appropriate repetition number. Of course, that is less flexible than option 2. The main tradeoff here is flexibility vs DCI overhead, as everyone knows. For the fallback DCI, what I meant is that with fallback DCI, the extra flexibility with option 2 is not there anyway. To Nokia: I vaguely recall some SI sim results show that, if UE specific beamforming is not available, i.e., gNB can only use omni-directional beam, then this effectively broadcast DCI is coverage bottleneck? |
| LG | To be clear, we support option 1 so basically agree with FL proposal. However, we think 1 bit DCI enhancement may be necessary for option 1, so “No DCI change or 1 bit DCI increment” would be better for us. |
| Spreadtrum | Support. |
| ETRI | We support the proposal. |
| Xiaomi | support |
| OPPO | We basically would also like to confirm the number of different repetitions to be supported by both options. We wonder if too much repetition length to be indicated, the PRI could be insufficient.Can we agree the number together with the definition？  |

Based on the discussion in GTW on Thursday, we need further define the details of both option 1 and option 2 before make the down selection.

**FL Question: do you agree with the following formulation of option 1? If not, please provide your comments/reasons in the following table.**

* **Option 1 (without DCI enhancement): Enhance RRC signaling to allow configuration of PUCCH repetition factor per PUCCH resource. Reuse Rel-15 PUCCH indication mechanism based on “PUCCH resource indicator” (PRI) field and starting CCE index (when applicable) of DCI to indicate a PUCCH resource and its associated repetition factor.**
	+ **FFS: in additional to PRI and starting CCE index, use PDCCH aggregation level to indicate PUCCH repetition factor.**
	+ **FFS: RRC signaling enhancement details**

Companies are welcome to provide answers/comments to the above question in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Samsung | No. An “Option 1” should be concrete without FFS (OK with FFS for RRC signaling details).Also, we don’t think Option 1 works. Proponents of Option 1 should describe how/whether it works by providing an example for a configuration of a PUCCH resource set together with a number of repetitions per PUCCH resource and how the gNB can then assign resources for various UCI payloads corresponding to the PUCCH resource set. |

**FL Question: do you agree with the following formulation of option 2? If not, please provide your comments/reasons in the following table.**

* **Option 2 (with DCI enhancement): PUCCH repetition factor is explicitly indicated by DCI**
	+ **Option 2a: introduce a new field in DCI to indicate PUCCH repetition factor.**
		- **FFS : the number of bits for the new field**
	+ **Option 2b: increase the number of bits of an existing field in DCI for PUCCH repetition factor indication**
		- **FFS: the existing field is PRI or other field such as TPC**
		- **FFS: the number of increased bits for the existing field**
		- **FFS: the codepoints for PRI/TPC with repetition factor indication**
	+ **FFS whether there is a need for RRC update**

Companies are welcome to provide answers/comments to the above question in the following table.

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Samsung | Option 2a is sufficient. No apparent motivation for Option 2b.Option 2a is the simplest and allows full flexibility to the network to both indicate a PUCCH resource (no need for the scheduler to make any changes for indicating a PUCCH resource to Rel-17 UEs supporting PUCCH coverage enhancements) and to indicate the number of repetitions as needed for any UCI payload. 2 bits indicating “x, 2x, 4x, 8x” repetitions can capture a SINR range of 9 dB which is easily sufficient. It is noted that if “Option 2b” can use the TPC bits, so can “Option 2a” – no need to increase a number of bits for any existing field and no need for “Option 2b”. |

# DMRS bundling across PUCCH repetitions

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

## Use cases

In the LS R1-2104119 sent to RAN4, the following use cases were agreed.

For PUCCH repetitions, the following use cases are considered in RAN1. Among the following cases, RAN1 suggest RAN4 to prioritize the study on use case 3, 4a, 4b, and 5b for PUCCH repetitions.

   Use case 1: back-to-back PUCCH repetitions within one slot.

   Use case 2: non-back-to-back PUCCH repetitions within one slot.

‐   Use case 2a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use case 2b: other uplink transmissions in the middle of two PUCCH repetitions

   Use case 3: back-to-back PUCCH repetitions across consecutive slots.

   Use case 4: non-back-to-back PUCCH repetitions across consecutive slots.

‐   Use 4a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use 4b: other uplink transmissions in the middle of two PUCCH repetitions

   Use case 5: PUCCH repetitions across non-consecutive slots.

‐   Use case 5a: no uplink transmission in the middle of two PUCCH repetitions

‐   Use case 5b: other uplink transmissions in the middle of two PUCCH repetitions

Note: RAN1 assumes “back-to-back PUCCH repetitions” has zero gap in-between adjacent PUCCH repetitions.

Note: intervening “other uplink transmissions” can be either on the same component carrier or a different component carrier.

In the contributions submitted to this meeting, there are proposals to further prioritize several use cases for PUCCH repetitions.

ZTE Proposal 2: Support Use case 1 and Use case 3 for joint channel estimation or joint detection of PUCCH repetitions.

* Clarify that Use case 1 includes both PUCCH format 0 and PUCCH format 2.

ZTE Proposal 3: Decide whether to support Use case 2a/4a/5a for PUCCH repetitions depending on RAN4 further discussion.

ZTE Proposal 4: Do not support joint channel estimation for Use case 2b/4b/5b for PUCCH repetitions.

QC Proposal 5: Support the following use cases:

   Use case 3: back-to-back PUCCH repetitions across consecutive slots.

   Use case 4: non-back-to-back PUCCH repetitions across consecutive slots.

‐   Use 4a: no uplink transmission in the middle of two PUCCH repetitions

VIVO Proposal 2: Optimizations specifically for use case 1 and use case 2 for DMRS bundling for PUCCH repetitions should be avoided.

Given that only three companies discussed this topic in their contribution, FL would like to collect more input from companies before draw a conclusion on this topic. Companies please provide your answers/comment to the following questions.

**FL Question: Should RAN1 prioritize a subset of agreed use cases in RAN1 study? If Yes, should RAN1 prioritize use cases 3, 4a, 4b, and 5b as RAN1 suggested in R1-2104119 for RAN 4 study? If No, what are the use cases RAN1 should prioritize?**

|  |  |
| --- | --- |
| **Company name** | **Answer/comment to the above questions** |
| CATT | Yes, RAN1 should further prioritize a subset of agreed use cases in RAN1 study. From our perspective, use case 3, use case 4a and use case 4b should be prioritized.For use case 1 and use case 2, they are simply not typical for coverage enhancement scenario which implies PUCCH format with short duration is applied.For use 5, we also don’t think it is typical as it can only happens in the following scenarios:1. Invalid symbols in-between in TDD band which depends on RAN4’s further reply
2. UL transmission with higher priority overrides one of the PUCCH transmissions, which should be avoided to guarantee the coverage performance.
 |
| ZTE | Yes, we suggest to prioritize Use case 1 and Use case 3. Regarding Use case 1, short PUCCH repetition within one slot has been supported in Rel-17 URLLC WI. From the perspective of the requirements to keep phase continuity, there is no difference compared to Use case 3 according to RAN4 reply LS. Regarding Use case 2a/4a/5a, it depends on further RAN4 reply since RAN4 only confirms the feasibility of keeping phase continuity when UE is not required to meet the existing off power requirements. However, whether or how to define new off power requirements are still not decided yet.As for Use case 2b/4b/5b, it is very difficult or even impossible to make the other signals (e.g., PUSCH and SRS etc.) transmitted in the middle of two PUCCH repetitions have the same antenna port, occupied PRBs and UL power etc. Thus, we don’t think RAN1 should support such rather rare case. |
| Nokia/NSB | Yes, RAN1 should prioritize use cases 3, 4a, 4b, and 5b as suggested in R1-2104119 for RAN 4 study. If further prioritization must occur, then our preference is 3 > 4a > 4b > 5b. |
| China Telecom | Yes, we support to prioritize Use case 3 and 4.  |
| Intel | We are fine to prioritize the study in RAN1. We suggest to focus on case 3/4a. We do not think PUCCH repetition in a slot needs to be studied for joint channel estimation as this is not for coverage enhancement.  |
| Ericsson | **We think use cases 1-5 apply, but use cases 1 & 2 could be treated at a lower priority. Use cases 2b/4b/5b do not seem feasible and so don’t seem to need further consideration unless RAN4 can loosen the constraints on antenna port and possibly PRB and power.**At least inter-slot DMRS bundling should be beneficial from a coverage enhancement perspective. Use case 3 is the most straightforward, while use cases 4 and 5 should be beneficial especially for TDD, if they are indeed feasible. Prioritization among these cases can be after we have more clarity from RAN4.Sub-slot repetition for PUCCH is supported in Rel-17 for URLLC, and so use cases 1 & 2 can be of interest. However, we understand that common use cases for sub-slot repetition are for diversity and/or beam blocked scenarios. So one way forward would be to list use cases 1 & 2 as a lesser priority.Regarding the ‘a’ cases, we share ZTE’s concerns about the off power requirement, and would like further clarity on this from RAN4 before prioritizing these options. If the network will experience greater interference when DMRS bundling is configured, this will likely reduce the net benefit of the feature.For the ‘b’ cases, since PUCCH is a different set of antenna ports than SRS or PUSCH, we don’t see how the RAN4 restrictions to using the same antenna port can be maintained. But even if RAN4 can alleviate this restriction, PUCCH tends to have a different number of PRBs, and probably different power, than SRS or PUSCH. So unless RAN4 can loosen these constraints somehow, we don’t see why they should affect the design of DMRS bundling. |
| Lenovo, Motorola Mobility | Yes, we support prioritization of use cases in RAN1 for PUCCH repetition enhancements with DMRS bundlingWe suggest prioritizing back-to-back cases i.e. use case 1 and 3. For non-back-to-back cases, we would suggest to further wait for additional RAN4 reply for all remaining cases where phase continuity and power consistency could be an issue.  |
| Apple | Support FL’s proposal |
| Sharp | Use cases 3, 4a, and 4b should be prioritized. Use case 5 should be deprioritized because PUCCH repetitions don’t avoid UL slots, and commonly, there are DL slots in the middle of two PUCCH repetitions across non-consecutive slots. |
| vivo | Yes, RAN1 should prioritize a subset of use cases.Yes, Case 3, 4a, 4b, 5a, can be prioritized, and the feasibility for these cases has been confirmed by RAN4 if conditions are met. |
| NTT DOCOMO | Yes, we support to prioritize use cases 3, 4a, 4b, and 5 for DMRS bundling across PUCCH repetitions. |
| InterDigital | We are supportive of prioritizing use case 1, along with use cases 3, 4a, 4b, and 5b. Coverage enhancement for back-to-back transmission, regardless of within/across slots, should be considered in this release. |
| CMCC | Support to prioritize use case 3 and 4. Case 1 and 2 could be deprioritized. And we need more clarifications of use case 5, when will this use case happens ? |
| Panasonic | Yes, we support to prioritize a subset of agreed use cases in RAN1 study as suggested in R1-2104119. |
| Qualcomm | For now we can prioritize Cases 3 and 4a. Other cases are either not very relevant or are only feasible under rare circumstances as per RAN4 feedback as also mentioned by several other companies. |
| Samsung | Prioritize cases 3/4/5. |
| WILUS | Yes, we support to prioritize use case 3, 4a, 4b, and 5b. |
| LG | In our understanding, at least case 1 and 2 should be deprioritized and case 3, 4 and 5 should be prioritized considering PUCCH repetition is supported only for format 1, 3 and 4 that repetition is performed across number of slots, not within a slot. |
| Spreadtrum | Yes, we support to prioritize the back-to-back cases, e.g., cases 1 and 3. |
| ETRI | We support the case where no other UL transmission between repetitions. We think case 3,4a,5a,2b can be prioritized. |
| Xiaomi | Yes, we support to prioritize the case 3 4 |
| OPPO | We should support case 3 and 4 prioritized.The motivation is we only consider long formats for the enhancement, not see the point for short formats. |

Based on companies input, majority companies support to prioritize use case 3, 4a, and 4b.

**FL proposed conclusion: For PUCCH repetitions, the following use cases are prioritized in RAN1 work.**

**   Use case 3: back-to-back PUCCH repetitions across consecutive slots.**

**   Use case 4: non-back-to-back PUCCH repetitions across consecutive slots.**

**‐   Use 4a: no uplink transmission in the middle of two PUCCH repetitions**

**‐   Use 4b: other uplink transmissions in the middle of two PUCCH repetitions**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Samsung | Use case 5 (PUCCH repetitions across non-consecutive slots) should be prioritized.Most NR bands are TDD and that is where the coverage needs to be mostly enhance.We are OK to include Cases 3 and 4 but they are of less importance compared to Case 5. |

## Signalling mechanism to enable DMRS bundling across PUCCH repetitions

In RAN1 104-e, the following agreements were made.

Agreements:

Subject to the prerequisites of DMRS bundling for PUCCH repetitions, support enabling PUCCH repetitions with DMRS bundling via RRC configuration.

* FFS: the configuration is per UE or per PUCCH resource.
* FFS: whether additional dynamic signaling is needed to enable/disable PUCCH repetitions with DMRS bundling
* FFS: necessity of additional signaling/configuration of DMRS bundling duration/window and associated size

Based on the above agreement. There are three open issues for further study.

Question 1: the RRC configuration to enable PUCCH repetition is per UE or per PUCCH resource?

Companies’ views submitted in the contributions are the following:

* Per UE: HW/HiSi, CATT, ETRI, Samsung, Xiaomi, Nokia
* Per PUCCH resource: QC, Apple, NEC, DCM

Question 2: whether additional dynamic signaling is needed to enable/disable PUCCH repetitions with DMRS bundling?

Companies’ views submitted in the contributions are the following:

* Not needed: CT, HW/HiSi, Nokia
* Needed: Xiaomi, Interdigital

Regarding the details of dynamic signaling, there are a few proposals.

Interdigital Proposal 3: Support a grant-type dependent index which indicates to the UE which PUCCH repetitions to bundle

Xiaomi Proposal 4: Multiple semi-static DMRS bundling configurations can be configured by RRC for per UE, and one of the configurations is activated through DCI signaling.

Question 3: Whether/how to design additional signaling/configuration of DMRS bundling duration/window and associated size?

The following proposals are submitted in contributions.

HW Proposal 5: A common design for both PUCCH and PUSCH is supported, regarding to the signaling/configuration of DMRS bundling duration/window and associated size.

ZTE Proposal 5: Specify a time domain window for PUCCH repetition.

* A UE reports a same time domain window size for PUSCH and PUCCH.

CMCC Proposal 3:

* For the design of frequency hopping, the DMRS bundling of PUSCH should could be the starting point of PUCCH.

QC Proposal 6: Similar to PUSCH joint channel estimation, RAN1 specifies time domain window(s) over which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements.

* Support multiple non-overlapping time domain windows for joint channel estimation over PUCCH repetitions.
* Window is determined based on semi-static slot format configuration.
* Window duration is in unit of physical slots.
* All windows have the same window duration.
* FFS: determine start of a window.

CT Proposal 5: For joint channel estimation, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.

Interdigital Proposal 4: For a hopping pattern that includes all of K repetitions in a hop, configure one time window matching the duration of a hop.

Intel Proposal 2

* A time domain window is specified for joint channel estimation over multiple PUCCHs, during which a UE is expected to maintain power consistency and phase continuity.
	+ The time domain window is defined based on the number of repetitions or slots.
	+ The time domain window may be configured by higher layers.
	+ When inter-slot frequency hopping with inter-slot bundling is applied, the time domain window is determined by the bundle size.
* Within the time domain window, UE needs to maintain same Tx power, precoder and frequency resource for joint channel estimation over multiple PUCCHs.

Panasonic Proposal 2: Specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements.

Panasonic Proposal 3: For the indication of the length of time domain window, enhance RRC signaling to allow configuration of the length of time domain window per PUCCH resource. Enabling/disabling and the length of time domain window are indicated via reusing PUCCH resource indicator field. PUCCH resource indicator field should be extended for further flexibility.

LG Proposal 3: We should revisit DMRS bundling across PUCCH repetitions after joint channel estimation for PUSCH

Sharp Proposal 4: For DMRS bundling, a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH transmissions subject to power consistency and phase continuity requirements should be adopted.

DCM Proposal 2: The same mechanism of DMRS bundling across repetitions discussed in PUSCH enhancement can be applied for PUCCH enhancement.

Lenovo Proposal 2: For supporting joint channel estimation with DM-RS bundling across multiple PUCCHs for coverage enhancements in NR Rel-17, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.

Nokia Proposal 4. No additional semi-static/dynamic signalling is introduced for configuring DMRS bundling window and associated size.

For DMRS bundling for PUCCH repetitions, majority companies support to define a time domain window, similar to what was agreed for PUSCH repetition. Therefore, the following FL proposal is made.

**FL proposal 2: For DMRS bundling for PUCCH repetitions, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.**

* **Strive for common ~~signaling mechanism~~ design of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.**
* **~~FFS whether use the same time domain window size for PUCCH repetitions and PUSCH repetitions.~~**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| CATT | We are generally fine with the proposal.For the FFS point, the intention is to use the same set of time domain window sizes for a UE instead of mandating an exact same window size for PUSCH transmission and PUCCH transmission? Or the same window size is always configured/indicated per UE which is applied to both PUCCH and PUSCH equally? |
| ZTE | Fine with the proposal in general.Regarding the FFS point, we also want to clarify that whether it is from UE capability reporting perspective or from gNB configuration perspective or both? |
| Nokia/NSB | Fine with the main sentence of the proposal. Not fine with the first bullet, given that RAN1 has not agreed how the time domain window is to be defined, and if it requires configuration (it depends on the design). We suggest the following modifications:**FL proposal 2: For DMRS bundling for PUCCH repetitions, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.*** **Strive for common design ~~signaling mechanism~~ of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.**
* **FFS whether use the same time domain window size for PUCCH repetitions and PUSCH repetitions.**
 |
| China Telecom | We support this proposal. Nokia’s modification is also fine with us. |
| Intel | We are fine with the proposal. |
| Ericsson | **Agree with the proposal as modified by Nokia, except that we prefer the FFS on window size be dropped.****FL proposal 2: For DMRS bundling for PUCCH repetitions, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.*** **Strive for common design ~~signaling mechanism~~ of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.**
* **~~FFS whether use the same time domain window size for PUCCH repetitions and PUSCH repetitions.~~**

It seems too early to address whether the same window size is used for PUSCH and PUCCH. This seems to assume that PUSCH and PUCCH are transmitted in a sufficiently similar way that the same size can be used. PUSCH and PUCCH may have different spatial relations; PUCCH is transmitted on its own (single) antenna port, while PUSCH supports UL MIMO; PUCCH is transmitted with few PRBs, while PUSCH is not necessarily so, and requirements for PUCCH or PUSCH coherence could vary given all these factors. So we would prefer further discussion, and probably more inputs from RAN4 on window size determination, before concluding on any commonality between PUCCH and PUSCH. |
| Lenovo, Motorola Mobility | We support the FL proposal and agree to that the enhancements agreed for PUSCH should be applicable for PUCCH, whenever possible. |
| Apple | Support FL’s proposal |
| Sharp | We support the FL proposal. |
| vivo | SupportThere is no need to define a new mechanism for PUCCH in addition to that for PUSCH unless issues specifically for PUCCH repetitions are identified. |
| NTT DOCOMO | We support the FL proposal. |
| InterDigital | We are ok with the modification from Nokia. |
| CMCC | No problem with defining a time domain window to facilitate further discussion. In the discussion in JCE of PUSCH, companies have different understanding about the time domain window. One is that it is a UE capability. In this situation, the time window should be same for PUSCH and PUCCH, unless the RAN4 provides more information stating that those two channels could have different durations. So for the FFS, based on current RAN4’s information, PUSCH and PUCCH should have the same capability of maintaining the power and phase continuity. The other is that the time domain window is used to indicate or scheduling the transmissions. Since the PUCCH repetitions could be configured in the RRC and indicated through DCI, the time domain window could be bundled with the PUCCH repetition configurations. It maybe a little different from the situation in PUSCH, in which the time domain window is also indicated through scheduling. I am hesitated to say those two kinds of design are exactly common, though the spirits are similar.  |
| Panasonic | We are fine with the FL’s proposal. |
| Qualcomm | We are okay with the proposal and changes suggested by Nokia and Ericsson. We agree with Ericsson that in all likelihood the choices of time domain window duration will be different between PUCCH and PUSCH. With PUCCH we only have to worry about pi/2 BPSK and QPSK, while with PUSCH, there are additional modulation orders to consider. Thus the configurations, and their dependence on modulation order needs more discussion and input from RAN4. |
| Samsung | Support the update from Nokia |
| WILUS | We support the FL’s proposal and also fine with the modification from Nokia. |
| LG | We support FL proposal. Since only specifying the time domain window for joint channel estimation of PUSCH is agreed and details of it is ongoing, we think time domain window for PUCCH, i.e., DMRS bundling for PUCCH repetition, should be discussed after basic framework for PUSCH is agreed. |
| Spreadtrum | We support the FL proposal. |
| ETRI | We are fine with the proposal. |
| Xiaomi | Support the FL’s proposal. |
| OPPO | We share views from Ericsson, the mechanism many not be identical.Best regards. |

Agreement: For DMRS bundling for PUCCH repetitions, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUCCH repetitions subject to power consistency and phase continuity requirements.

* Strive for common design of the time domain window for PUSCH/PUCCH with DMRS bundling as much as possible.

## Inter slot freq hopping enhancement with DMRS bundling

In RAN1 104e, the following agreements were made.

Agreements: Subject to the prerequisite of DMRS bundling for PUCCH repetitions, enhance inter-slot frequency hopping pattern for PUCCH repetitions with DMRS bundling.

* FFS: details in inter-slot frequency hopping pattern enhancement, e.g., additional frequency hopping patterns than Rel-16.
* Strive for common design for PUSCH/PUCCH with DMRS bundling as much as possible

In companies’ contributions, the following proposals are made regarding to the topic of inter slot frequency hopping enhancement with DMRS bundling.

HW Proposal 2: Inter-slot frequency hopping pattern with inter-slot bundling can be considered for the inter-slot frequency hopping pattern enhancement.

ZTE Proposal 6: Inter-slot frequency hopping with inter-slot bundling to enable cross-slot channel estimation among repetitions per bundle is supported.

Spreadtrum: For example, to facilitate joint channel estimation, the repetitions of PUCCH in consecutive UL slots can be mapped to the same hop as many as possible.

CATT Proposal 6: Hopping interval of the enhanced inter-slot frequency hopping pattern can be equal to the DMRS bundling window duration/size.

QC Proposal 8: When the PUCCH repetition is enabled, the frequency hop for PUCCH repetition transmission is determined based on the repetition count for each PUCCH transmission occasion.

QC Proposal 9: When inter-slot frequency hopping is configured with DMRS bundling, all PUCCH transmissions in a single time domain DMRS bundling window belong to the same hop.

OPPO Proposal 4: For enhancement, the PUCCH repetition with frequency hopping can introduce 2 bundles of slots. Each bundle of slots can be transmitted in different PRBs.

Interdigital Proposal 5: Support a hopping pattern with DMRS bundling where during one hop, all of K repetitions are included.

Intel Proposal 3

* Inter-slot frequency hopping with inter-slot bundling is supported for PUCCH enhancement.
	+ The bundle size may be configured higher layers or determined based on the number of repetitions.

Apple Proposal 3: Specify the inter-slot frequency hopping pattern to enable the conjunction operation of repetition, frequency hopping and joint channel estimation.

Panasonic Proposal 4: One or more lengths of time domain windows are configured to be jointly used with inter-slot frequency hopping / precoder cycling.

* Each of the one or more lengths of time domain windows is used for the same frequency allocation in inter-slot frequency hopping procedure.

ETRI: Proposal 4: 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.

Xiaomi: Proposal 3：Introduce configurable additional inter-slot frequency hopping patterns for PUCCH repetitions with DMRS bundling.

DCM Proposal 4: The duration per frequency hop should be implicitly determined by the time domain window, where the duration per frequency hop is equal to a time domain window size for joint channel estimation.

Lenovo Proposal 3: For supporting joint channel estimation with DM-RS bundling across multiple PUCCHs for coverage enhancements in NR Rel-17, support multi-slot frequency hopping and multi-slot DM-RS bundling for joint channel estimation for entire hop:

* Association between frequency hop duration and time-domain window should be supported such that explicit indication of both the frequency hop duration and time-domain window is not needed
	+ Time-domain window size can be equal to the frequency hop duration
* At least hop duration of 2 slots should be supported with DM-RS bundling

Nokia Proposal 5. For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation:

* RAN1 to specify at least the following frequency hopping approach:
	+ UE switches frequency hop for the repetitions after a DL reception occasion that the UE is expected/configured to monitor/receive or after an UL transmission with different settings (e.g., in antenna port, occupied PRBs and UL power) than the PUCCH repetitions.

For inter slot frequency hopping with DMRS bundling, majority companies support additional frequency hopping patterns than Rel-16 to allow DMRS bundling within a duration per frequency hopping (a.k.a., time domain hopping interval as defined for PUSCH repetition). Majority companies support to set the bundle size equal to the time domain window size (to keep power consistency and phase coherency).

**FL Proposal 3: For inter slot frequency hopping with DMRS bundling, all PUCCH repetitions in a frequency hopping duration (similar to the time domain hopping interval defined for PUSCH repetition) belong to the same frequency hop.**

* **The frequency hopping duration equals to the size of time domain window where power consistency and phase coherency can be maintained.**

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

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| CATT | Support. |
| ZTE | Though, we are fine with the proposal, we feel it may be better to first decide how to determine the time domain window (e.g., the start and the length etc.), and then to decide whether the FH could be based on the time domain window. |
| Nokia/NSB | Fine with the general principle underlying the proposal, however we also think that further discussions should be had before agreeing to it. More specifically: shouldn’t we first discuss details of the time domain window, to understand how the UE should handle events like DL monitoring occasions within the window, if any/applicable, UL transmissions with different settings within the window, if any/applicable, and so on? We think that once framework is clear in this regard, adding support to inter-slot FH on top of it is quite an incremental effort. We prefer avoiding putting the cart before the horse, if possible. |
| China Telecom | Since similar issue is also discussed for PUSCH about the relationship between time domain window size and DMRS bundling size. We think we can postpone this issue after the agreement for PUSCH is achieved. |
| Intel | We are fine with the main bullet in principle, but we suggest to follow similar terminology as agreed for PUSCH enhancement, e.g., inter-slot frequency hopping with inter-slot bundling is supported for PUCCH. For the sub-bullet, our view is that time domain window size can be larger than bundle size for inter-slot frequency hopping. But within the bundle size, power consistency and phase continuity need to be maintained.  |
| Ericsson | Also prefer to postpone.For us, what is more critical to agree is how the hopping pattern is adjusted. The phase continuity & power consistency constraints can then determine which DMRSs in which hops can be combined. Tradeoffs on channel estimation gain vs. frequency hopping gain should be quantified to allow the right frequency hopping patterns to be defined. |
| Lenovo, Motorola Mobility | We support the FL proposal.  |
| Apple | Let’s have more progress on time window.  |
| Sharp | We support the FL proposal. |
| Vivo | We support the FL proposal. |
| NTT DOCOMO | We support the FL proposal. |
| InterDigital | We support inter-slot bundling for inter-slot FH in Proposal 7 in our contribution. We are also supportive of using the same terminology as in PUSCH inter-slot FH, “inter-slot frequency hopping with inter-slot bundling”. |
| CMCC | Fine with the main bullet. For the sub bullet, it is proposed to be updated as below, * **The frequency hopping duration equals to or smaller than the size of time domain window where power consistency and phase coherency can be maintained.**
 |
| Panasonic | We prefer to postpone this issue for seeing more progress on time domain window and/or the similar issue on PUSCH.In our view, the relation with inter-slot precoder cycling should be taken into account in addition to frequency hopping. If the discussion is for UE not to support precoder cycling, we are supportive to the FL proposal. If the discussion is for UE supporting precoder cycling, we would like to discuss the sub-bullet further. |
| Qualcomm | We are in general okay with the proposal, but we can wait for more clarity on time domain window configuration. |
| Samsung | Support the proposal.  |
| WILUS | We are fine with the main-bullet in FL’s proposal. For the sub-bullet, discussion can be postponed until the output has made on PUSCH. |
| LG | We agree with enhancement of frequency hopping for DMRS bundling is needed and same DMRS bundle should belong to same frequency hop. However whether the frequency hopping duration is equal to the size of time domain window or not is being discussed in joint channel estimation for PUSCH, so for the main bullet, it should be discussed after joint channel estimation for PUSCH is agreed for unified frame structure. In short, it would be better for us:**For inter slot frequency hopping with DMRS bundling, all PUCCH repetitions in a DMRS bundle ~~frequency hopping duration~~ (similar to the time domain hopping interval defined for PUSCH repetition) belong to the same frequency hop.** * **~~The frequency hopping duration equals to the size of time domain window where power consistency and phase coherency can be maintained.~~**
 |
| Spreadtrum | Postpone this issue and wait for more progress of time domain window  |
| ETRI | We tend to agree with the proposal, and we prefer to have the unified solution between PUSCH and PUCCH. |
| Xiaomi | We agree with the main bullet that enhancement of frequency hopping for DMRS bundling is needed and same DMRS bundle should belong to same frequency hop. For sub-bullet, we think frequency hopping duration can be smaller or equal to the time window size, and maybe it can keep the same conclusion with the output has made on PUSCH. |
| OPPO | We suggest postpone the discussion, seem time window may be only reported by UE or other choices.  |

# Others

There are a few other proposals mentioned in submitted contributions to this agenda. FL’s initial assessment is that the discussion of those proposals can be deprioritized, comparing to proposals in Section 2 and Section 3.

[[R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip)]: The maximum number of repetitions for transmission of PUCCH repetition is 32.

[[R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip)]: The dynamic PUCCH repetition mechanism should be applied to all PUCCH formats and all UCI types including A-CSI.

[[R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip)]: Further study the benefit of gNB estimated inter-slot relative phase correction for PUCCH, addressing how frequency selective such phase corrections would need to be for UEs and/or conditions that do not sufficiently support maintaining inter-slot relative phase.

* Consider operation with and without frequency hopping and with and without transparent transmit diversity.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: For a PUCCH (or PUSCH) repetition with DMRS bundling, only TPC indicated by a unicast DCI is applied, i.e. TPC on GC-DCI 2-2 is ignored.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: Unicast DCI with a TPC command implicitly indicates that DMRS bundling is off, from the occasion that new TPC is applied.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: Specify conditions under which a PUCCH with dynamic indication of repetition number may overlap with another PUCCH repetitions without dynamic indication of repetitions.

[[R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip)]: 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.

[[R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip)]: A UE updates the CLPC adjustment state per time domain window.

# References

|  |  |  |
| --- | --- | --- |
| [R1-2104243](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104243.zip) | Discussion on PUCCH coverage enhancement | Huawei, HiSilicon |
| [R1-2104333](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104333.zip) | Discussion on coverage enhancements for PUCCH | ZTE |
| [R1-2104379](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104379.zip) | Discussion on PUCCH enhancements | vivo |
| [R1-2104438](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104438.zip) | Discussion on PUCCH enhancements | Spreadtrum Communications |
| [R1-2104540](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104540.zip) | Discussion on PUCCH enhancement | CATT |
| [R1-2104628](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104628.zip) | Discussion on PUCCH enhancements | CMCC |
| [R1-2104688](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104688.zip) | PUCCH enhancements | Qualcomm Incorporated |
| [R1-2104795](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104795.zip) | PUCCH enhancements for coverage | OPPO |
| [R1-2104849](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104849.zip) | Discussion on PUCCH enhancements | China Telecom |
| [R1-2104862](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104862.zip) | Discussions on PUCCH enhancements | InterDigital, Inc. |
| [R1-2104922](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104922.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2104978](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104978.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2105035](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105035.zip) | Discussion on PUCCH enhancements | Intel Corporation |
| [R1-2105122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105122.zip) | PUCCH coverage enhancement | Apple |
| [R1-2105149](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105149.zip) | Discussion on PUCCH enhancement for NR coverage enhancement | Panasonic Corporation |
| [R1-2105224](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105224.zip) | PUCCH enhancements | ETRI |
| [R1-2105239](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105239.zip) | PUCCH enhancements | ETRI |
| [R1-2105257](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105257.zip) | Discussion on PUCCH enhancements | NEC |
| [R1-2105328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105328.zip) | PUCCH enhancements | Samsung |
| [R1-2105360](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105360.zip) | PUCCH enhancements | ETRI |
| [R1-2105491](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105491.zip) | Discussions on coverage enhancement for PUCCH | LG Electronics |
| [R1-2105578](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105578.zip) | PUCCH coverage enhancement | Xiaomi |
| [R1-2105643](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105643.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2105655](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105655.zip) | PUCCH Dynamic Repetition and DMRS Bundling | Ericsson |
| [R1-2105714](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105714.zip) | PUCCH enhancements | NTT DOCOMO, INC. |
| [R1-2105776](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105776.zip) | Enhancements for PUCCH repetition | Lenovo, Motorola Mobility |
| [R1-2105904](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105904.zip) | PUCCH coverage enhancements | Nokia, Nokia Shanghai Bell |