3GPP TSG-RAN WG1 Meeting #106bis-e R1-21xxxxx

e-Meeting, 11th – 19th October, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary #2 for [106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4

Document for: Discussion, Decision

# 1 Introduction

This document summarizes the contributions made under the “Enhancements for PUCCH Formats 0/1/4” agenda item of the Rel-17 work item "Extending current NR operation to 71 GHz."

The following email thread is assigned for discussion of this topic:

[106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 with checkpoints for agreements on October 14 and 19 – Steve (Ericsson)

# 2 PUCCH Resource Set Prior to RRC Configuration

## 2.1 Potential RB Shortage

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel [11] | **Proposal 4: RAN1 should further discuss possible enhancements to PUCCH resource sets before dedicated PUCCH resource configuration such as additional starting symbol or OCC index similarly as done in Rel.16 NR-U.** |
| Qualcomm [17] | **Proposal 3: Based on construction process in example 1, a common PUCCH resource is invalid if some of its occupied RBs is outside the initial UL BWP. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  **Proposal 4: Based on construction process in example 1, if one of common resource with r\_pucch>=8 uses some RBs occupied by common resource with r\_pucch<8, this resource should be invalidated by spec. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.** |
| Futurewei [3] | ***Observation 1. The prior Note on no further enhancement on RB shortage issue was included by the agreement at the time of the discussion when the maximum number of RBs were 12/3/2 for 120/480/960kHz SCS were preliminary, while the numbers were finalized one meeting afterwards. It has not been discussed whether it is needed for the RB shortage issue to be revisited under the newly allowed maximum RB numbers 16/16/16 for 120/480/960kHz SCS.***  ***Proposal 2. The increase of the maximum number of RBs can make the RB shortage problem substantially worse, so it is warranted to confirm whether or not RAN1 wish to address the RB shortage problem.***  ***Observation 2. Alt-4 in the relevant discussion in RAN1#105-e is expected to remain as a feasible option such that 16 PUCCH resources can be made available if additional OCCs and/or SLIVs are introduced for some rows of the table. Alt-5 can also alleviate the RB shortage issue by not allowing large PRB offsets when multiple RBs are configured.*** |
| LGE [15] | **Proposal #4: To address the potential shortage of PUCCH resources for the initial PUCCH resource set resulting from using multi-PRB to transmit PUCCH formats 0 and 1, consider the following alternatives:**   * **Alt. 1: Use only valid resources in the frequency domain** * **Alt. 2: Support additional starting symbol and OCC index**   **Proposal #5: Considering the available number of RBs in the initial BWP and more than 1 RB allocated for an initial PUCCH resource, discuss how to configure the hopping distance to obtain hopping gain equally for each initial PUCCH resource.** |
| Ericsson [8] | **Observation 1 According to previous agreements, the following enhancements for PUCCH resource sets prior to RRC configuration are out-of-scope:**   * + **Introduction of additional time domain starting positions and/or additional OCCs**   + **Support of a new RE mapping scheme (e.g., sub-PRB interlaced mapping)**   + **Equalization of hopping distance for the PUCCH resources within a set** |
| OPPO [6] | **Proposal 2: The potential RB shortage issue prior to RRC configuration can be handled by gNB implementation.** |
| Nokia [9] | ***Observation:*** *Further enhancements for PUCCH resource sets to mitigate RB shortage or to equalize frequency hopping distance should not be considered.* |
| Samsung [10] | **Proposal 2: RAN1 shall not re-open the discussion on the RB shortage issue before RRC connection.** |
| ZTE [4] | **Observation 1: RB shortage issue can be resolved through appropriate gNB configuration of BWP and RB number.**  **Proposal 1: No further enhancements on RB shortage issue should be considered.** |

### Summary of Potential RB Shortage

Company views on whether or not to re-open discussion on potential RB shortage issue

* Do not re-open discussion:
  + Qualcomm, Ericsson, OPPO, Nokia, Samsung, ZTE
* Further discuss:
  + Intel, Futurewei, LGE

Several companies point out that even if there could be an RB shortage issue for some combinations of values of {indicated row index of Table 9.2.1-1, indicated number of RBs, configured initial UL BWP size, indicated PUCCH resource index r\_PUCCH}, such ccombinations can be avoided by gNB implementation. Several companies also refer to the following note from an Agreement in RAN1#105-e that implies that there should be no further enhancements to address a potential RB shortage issue. Some companies point out that this note was agreed when it had not yet been agreed to increase the maximum number of RBs for a PUCCH resource from 12 to 16, and thus have increased concerns on RB shortage.

* Note: No further enhancements on RB shortage issue and frequecy hopping distance issue should be considered for PUCCH resource sets prior to RRC configuration

As per normal working procedure, consensus will be needed on any enhancement to address a potential RB shortage issue. Given that there is not even consensus to discuss the issue, it appears unlikely that consensus on potential enhancements could be agreed. Given the situation, the moderator proposes the following conclusion.

### **Conclusion #1 (Potential RB Shortage)**

* Do not re-open the discussion potential RB shortage and frequency hopping distance issues for PUCCH resource sets prior to RRC configuration.

Please provide your company view on Conclusion #1. Please consider that we should try to avoid spending valuable time on issues that have little chance of consensus.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Huawei/HiSilicon | Since the system will be functional and the issue can be handled by implementation, we do not see any need to re-open the discussion. |
| Nokia, NSB | Agree with the proposed conclusion. |
| OPPO | We agree with conclusion #1. The potential RB shortage issue can be handled entirely by gNB implementation. |
| vivo | First, we’d like to clarify that the discussion of RB shortage is for common PUCCH resoruce sets before dedicated PUCCH resource configuration instead of prior to RRC. Our understanding is that the common PUCCH resource can also be applied after RRC if there’s no dedicated PUCCH resource configuration.    We are OK with Conlusion #1 with the scope (i.e. for common PUCCH before dedicated PUCCH resource configuration) clarified. |
| Intel | Many thanks to the FL for the discussion, and summary.  Regarding this topic, and the aforementioned note, as the FL poitnted out, our understanding is that this note was agreed under the assumption that the maximum number of PRBs used for enhanced PUCCH would remain the same as per initial agreement (12/3/2 for 120, 480 and 960 KHz SCS), and in that scenario/assumptions we indeed thought that there was no technical motivation to enhance the resources sets before RRC configuration. However, since now based on the recent agreements made during the last meeting the number of PRBs could be potentially configured up to 16 for 480 KHz SCS, and since as shown in our prior tdoc 12 PRBs is actually a realistic value that could be indeed used, we have concerns that if we leave the resources sets before RRC configuration as in legacy, the available bandwidth would not be enough to support frequency domain partitioning, and multiplexing capability will be highly constrained even for feasible and frequently used values.  As proposed, while the network could indeed be imposed by implementation to not use any of the resource sets for which this issue occurs, this would effectively highly limit the multiplexing capability of the network, and in particular for 480 KHz SCS if NRB>11, 4/13 resouce sets could not be used at all, which represents more than 33% of the total resorce sets that could be used for PUCCH format 1. For this reason, we would rather prefer to mitigate this issue. |
| InterDigital | We support conclusion #1. |
| Qualcomm | We are fine not to re-open the discussion of potential RB shortage issue due to previous agreement. But as we stated in our contribution, we think the spec should make it explicit of the fact there may be RB shortage issue (though we can not address it during this WI) and thus to invalidate “out of band” and “one of overlapping” common PUCCH resource so that UE is not expected to be scheduled with such a resource so UE doesn’t need to have logic to handle this. |
| Apple | We are fine with the conclusion based on the previous agreement. |
| Futurewei | We are fine that this issue does not get addressed by the WI for time limitation, while we agree with Qualcomm that it is better to make explicit that such an issue exists for the invalidation purpose. |
| CATT | Fine with the proposal. |
| Moderator | Based on the ammended wording suggested by vivo and the comment from Qualcomm, please see updated Conclusion #1a below.  The intention of the wording "separately discussed" is that this will become part of the FFS in Proposal #1a. |

### **Conclusion #1a (Potential RB Shortage)**

* Do not re-open the discussion potential RB shortage and frequency hopping distance issues for common PUCCH resource sets prior to dedicated PUCCH resource configuration.
* Note: whether or not the spec explicitly captures error cases related to a potential RB shortage issue will be separately discussed.

Please provide your company view on updated Conclusion #1a.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| NTT DOCOMO | We are fine with Conclusion #1a. |
| Qualcomm | We are fine with Conclusion #1a. |
| vivo | We’okay with Conclusion #1a. |
| LG Electronics | We still think that the potential shortage of PUCCH resources and the hopping distance equalization resulting from using multi-PRB to transmit PF 0/1 should be addressed. However, considering strong support from many companies, we can focus on the potential RB shortage issue capture in the Note. |
| Samsung | We are ok with the conclusion. |
| ZTE, Sanechips | We are fine with Conclusion #1a. |
| Lenovo, Motorola Mobility | We are fine with Conclusion #1a |
| Huawei, HiSilicon | We are fine with Conclusion #1a. |

The following conclusion was agreed in the GTW on 10/11:

### **Conclusion:**

* Do not re-open the discussion potential RB shortage and frequency hopping distance issues for common PUCCH resource sets prior to dedicated PUCCH resource configuration.
* Note: Whether or not the spec explicitly captures error cases related to a potential RB shortage issue will be separately discussed.

## 2.2 PUCCH Resource Set Construction

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel [11] | **Proposal 1: Independently of the PUCCH resource set the number of RBs used for each PUCCH resource is the same as that configured through SIB1.**  **Proposal 2: The first PRB index for each PUCCH resource is function of the offset provided in Table 9.2.1-1, but also the number of RBs, , over which the PUCCH transmission spans.**  **Proposal 3: TP1 is supported.**  --------------------------------------------TP#1 for Section 9.2.1 in TS 38.213 -----------------------------------------------  If and a UE is provided a PUCCH resource by pucch-ResourceCommon and is not provided useInterlacePUCCH-PUSCH in BWP-UplinkCommon  - the UE determines the first PRB index of the PUCCH transmission in the first hop as and the first PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes and is the number of PRBs for the PUCCH transmission.  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by pucch-ResourceCommon and is not provided useInterlacePUCCH-PUSCH in BWP-UplinkCommon  - the UE determines the first PRB index of the PUCCH transmission in the first hop as and the first PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| Qualcomm [17] | **Proposal 3: Based on construction process in example 1, a common PUCCH resource is invalid if some of its occupied RBs is outside the initial UL BWP. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  **Proposal 4: Based on construction process in example 1, if one of common resource with r\_pucch>=8 uses some RBs occupied by common resource with r\_pucch<8, this resource should be invalidated by spec. gNB should never schedule UE with such a resource, and UE shall treat it as an error case when it is scheduled to use such a common PUCCH resource.**  [Moderator Note] „construction process in example 1“ refers to Example Construction 1 in Section 7.2 of [1] |
| Futurewei [3] | ***Proposal 1. The equations in the Example Construction 1 by FL for addressing different rows in Table 9.2.1-1 is sufficient to calculate the lowest PRB indices as a function of the N\_RB and the RB offset.***  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1] |
| NTT DOCOMO [12] | *Proposal 1: How to design PUCCH resources before dedicated PUCCH configuration should be discussed based on the following three alternatives for frequency domain resource configuration considering multi-PRB allocation for PF0/1.*   * *Alt.1:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as * *Alt.2-1:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as * *Alt.2-2:*   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*   * + the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as     Fig.1: An example for Alt.1 of PUCCH resource sets before dedicated PUCCH configuration    Fig.2: An example for Alt.2-1 of PUCCH resource sets before dedicated PUCCH configuration    Fig.3: An example for Alt.2-2 of PUCCH resource sets before dedicated PUCCH configuration  [Moderator Note] Alt-1 corresponds to Example Construction 1 contained in Section 7.2 of [1] |
| LGE [15] | **Proposal #2: The PRB indices for enhanced PUCCH format 0/1 prior to RRC configuration can be obtained by following options:**   * **Option 1: Directly use the NRB value indicated by SIB1 to calculate the PRB indices** * **Option 2: The parameter X for the PRB offset scaling is configured separately and use it together with the NRB value to calculate the PRB indices.**   Option 2:  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  -     the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  -     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  -     the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  [Moderator Note] Option 1 corresponds to Example Construction 1 in Section 7.2 of [1].  **Proposal #3: Discuss whether special handling for the PUCCH resource set index 15 is necessary or not.** |
| Sony [13] | **Proposal 1: Support moderator’s Proposal 10 from RAN1#106-e meeting. The lowest-indexed RB of each PUCCH resource is a function of the and RB offset provided by Table 9.2.1-1 and can be computed according to Example Construction 1.**  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1]  **Observation 1: The network can select and so as to ensure that the lowest-indexed RB of each PUCCH resource is within the initial UL BWP. Alternatively, operations in 38.213 Section 9.2.1 can be performed modulo .** |
| Ericsson [8] | **Proposal 2 For 120 and 480 kHz SCS, reuse the Rel-15 PUCCH configuration table 9.2.1-1 for configuration of PUCCH resource sets prior to RRC configuration for enhanced (multi-RB) PUCCH formats 0/1**   * + **As previously agreed, the number of RBs for each PUCCH resource in a set is *N*RB which is signaled in SIB1**   + **The lowest-indexed RB for each PUCCH resource is a function of *N*RB**   + **The following example change to Rel-16 specifications can be recommended to the editor of 38.213 to use at his discretion**   If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| CATT [7] | Option1: The gNB uses SIB1 to configure an index of PUCCH resource sets which is associated with the number of RBs similar to the table in [3].  **Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Index** | **PUCCH format** | **First symbol** | **Number of symbols** | **Number of RBs** | **PRB offset** | **Set of initial CS indexes** | | 0 | 0 | 12 | 2 | 1 | 0 | {0, 3} | | 1 | 0 | 12 | 2 | 1 | 0 | {0, 4, 8} | | 2 | 0 | 12 | 2 | 12 | 3 | {0, 4, 8} | | 3 | 1 | 10 | 4 | 1 | 0 | {0, 6} | | 4 | 1 | 10 | 4 | 1 | 0 | {0, 3, 6, 9} | | 5 | 1 | 10 | 4 | 12 | 2 | {0, 3, 6, 9} | | 6 | 1 | 10 | 4 | 12 | 4 | {0, 3, 6, 9} | | 7 | 1 | 4 | 10 | 1 | 0 | {0, 6} | | 8 | 1 | 4 | 10 | 1 | 0 | {0, 3, 6, 9} | | 9 | 1 | 4 | 10 | 12 | 2 | {0, 3, 6, 9} | | 10 | 1 | 4 | 10 | 12 | 4 | {0, 3, 6, 9} | | 11 | 1 | 0 | 14 | 1 | 0 | {0, 6} | | 12 | 1 | 0 | 14 | 1 | 0 | {0, 3, 6, 9} | | 13 | 1 | 0 | 14 | 12 | 2 | {0, 3, 6, 9} | | 14 | 1 | 0 | 14 | 12 | 4 | {0, 3, 6, 9} | | 15 | 1 | 0 | 14 | 1 |  | {0, 3, 6, 9} |   The values in the table indicates number of RBs for 120 kHz SCS. For 480 or 960 kHz SCS, the values should be scaled by 1/4 or 1/8. If the value for 480 or 960 kHz SCS is not an integer, it needs to be rounded up.  **Proposal 3 For common PUCCH resource sets, the gNB needs to indicate the number of RBs for PUCCH format 0/1/4 of 120 kHz SCS. For 480 or 960 kHz SCS, the values can be scaled by 1/4 or 1/8.**  **Proposal 4 The PRB offset value also needs to be scaled by the number of RBs for inter-cell frequency division multiplexing, which ensure that the multi-RB PUCCH resources in the set do not overlap each other.**  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| OPPO [6] | **Proposal 1: The UE can determine the PRB index and the initial cyclic shift index in the PUCCH resource sets prior to RRC configuration based on the simple modification in 38.213 Section 9.2.1.** |
| Nokia [9] | ***Proposal 2:*** *PUCCH resource RBs are defined so that RBs of the PUCCH resources in the cell-specific resource set are not partially overlapping. The lowest PRB indexes of PUCCH resource frequency hops are defined as and as for the first 8 PUCCH resource indexes and with and as for the last 8 PUCCH resource indexes.* |
| Apple [16] | ***Proposal 1:*** *Adopt Example Construction 1 in [12] for the PUCCH resource sets before dedicated PUCCH resource configuration*   * *The UE assumes that the number of RBs indicated in SIB1 can be used with any row of table 9.2.1-1 of 38.213* * *Modify the specification in 38.213 Section 9.2.1 for frequency hopping with the introduction of the multi-RB PUCCH enhancement.*   + *Turn off frequency hopping in the case that N\_RB is on the order of the bandwidth* |
| Samsung [10] | **Proposal 1: Before RRC connection, support the starting RB for a PUCCH resource based on the indicated number of RBs.**  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as  If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*  - the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as  - the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as |
| ZTE [4] | For the details of PUCCH resource, the determination of the lowest or starting PRB indexes in [3] can be discussed further.  **Proposal 2: No further enhancements on frequency hopping distance issue should be considered.** |
| Interdigital [14] | ***Observation 1:*** *Different number of RBs for each row enables supporting a different number of RBs for different PUCCH formats, different first symbols, different numbers of symbols and different sets of initial CS indexes. However, the indication method actually reduces flexibility as number of RBs should be associated with each row.*  ***Observation 2:*** *Need of supporting different number of RBs for each PUCCH resource set is doubted as it can be further resolved by UE specific RRC configuration.*  ***Proposal 1:*** *It is preferred to support same number of RBs for all PUCCH resource sets* |
| vivo [5] | **Proposal 1: For PUCCH, the lowest PRB index of PUCCH is dependent on the NRB:** |
| Huawei [2] | ***Proposal 1: For 120 and 480 kHz SCS, UE determines PUCCH resources prior to RRC configuration based on the general extension (Example Construction 1).***  [Moderator Note] Example Construction 1 contained in Section 7.2 of [1] |

### Summary of Construction of PUCCH Resource Set Prior to RRC

In RAN1#106-e, the following construction of PUCCH resource sets prior to RRC configuration was discussed (see Section 7.2 of [1]), and this was referred to as “Example Construction 1.”

**Example Construction 1**:

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

Based on the proposals listed above from company contributions, there appears to be quite strong support for Example Construction 1 which is based on using Table 9.2.1-1 in 38.213 “as is” with N\_RB indicated in SIB1 (as previously agreed). Some companies support a variation of Example Construction 1 in which is scaled by a value other than N\_RB (e.g., by N\_RB / 2, by a configurable value X, or no scaling at all) [12] [15]. One company [7] proposes a variation whereby Example Construction 1 is used, but Table 9.2.1 is hardwired with a different value in each row (N\_RB = 1 or 12). The existing SIB1 parameter that indicates the row index of Table 9.2.1-1 would then implicitly indicate the number of RBs. However, it is the moderator’s understanding that the intention of the following agreement from RAN1#106-e is that a new SIB1 parameter would directly indicate the number of RBs.

Agreement:

* For PUCCH resource sets prior to RRC configuration, support a parameter in SIB1 that indicates the number of RBs for enhanced (multi-RB) PUCCH format 0/1

A summary of the above company is as follows:

* Alt-1: Support Example Construction 1 based on using the existing Table 9.2.1-1 “as is” with N\_RB indicated by a new parameter in SIB1:
  + Intel, Qualcomm, Futurewei, NTT DOCOMO (Alt-1), Sony, Ericsson, OPPO, Nokia, Apple, Samsung, ZTE(?), Interdigital (?), vivo, Huawei
* Alt-2: Variation of Alt-1 in which the RB offset in Table 9.2.1-1 ) is scaled by a value other than N\_RB
  + Scale by fixed value (e.g., N\_RB / 2 or no scaling)
    - NTT DOCOMO (Alt 2-1, 2-2)
  + Scale by configurable value X
    - LGE
* Alt-3: Support Example Construction 1 using a modification of Table 9.2.1-1 where a fixed value of N\_RB is hardwired per row of the table and N\_RB is implicitly indicated by the existing SIB1 parameter that indicates the row index of Table 9.2.1-1
  + CATT

Based on the strong support for Alt-1, it is proposed that Alt-1 is agreed, but with an FFS point on whether or not the RB offset is scaled by a value other than N\_RB, i.e., Alt-2.

An additional FFS can be added based on that several companies observe that there can be two potential error cases for some combinations of {indicated row index of Table 9.2.1-1, indicated number of RBs, configured initial UL BWP size, indicated PUCCH resource index r\_PUCCH}. The error cases are

* Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
* Case 2: A PUCCH resource with r\_PUCCH ≥ 8 can overlap the RBs of a PUCCH resource with r\_PUCCH < 8.

Companies have suggested that such potential error cases can be handled by one of the following approaches:

1. By implantation the gNB can avoid configurations where Case 1 and 2 could happen, e.g., [6],[13]
2. The UE behavior can be specified for Case 1 and/or Case 2, e.g., [17]

### **Proposal #1 (PUCCH Resource Set Construction Prior to RRC)**

* Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets prior to RRC configuration for multi-RB PUCCH formats 0/1
* As previously agreed, the number of RBs for each PUCCH resource in a set is N\_RB which is signaled in SIB1
* The lowest-indexed RB for each PUCCH resource is a function of N\_RB
* The following example change to 38.213 Section 9.2.1 can be recommended to the editor of 38.213 to use at the editor’s discretion (subject to resolution of the below FFS on the value of X)

---- Start ----

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

---- End ----

* FFS: Supported value of X. Down-select to one of the following alternatives:
  + Alt-1: X = N\_RB
    - Note: This alternative is mathematically equivalent to Example Construction 1 discussed in RAN1#106-e.
  + Alt-2a: X is a fixed value less than N\_RB, e.g., 1, N\_RB / 2, …
  + Alt-2b: X is configurable, e.g., via SIB1
* FFS: Whether it should be left to gNB implementation to avoid the following potential error cases, or whether/how UE behavior should be specified for these cases:
  + Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
  + Case 2: An indicated PUCCH resource with r\_PUCCH ≥ 8 can overlap the RBs of a PUCCH resource with r\_PUCCH < 8.

Please provide your company view on Proposal #1.

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| --- | --- |
| **Company** | **View/Position** |
| Moderator | Question to CATT: Due to almost unanimous support for Alt-1 or Alt-2 and the agreement from last meeting on the SIB1 parameter indicating N\_RB, can CATT compromise and accept Proposal #1?  Question to Apple: Is it still necessary to further discuss potential disabling of frequency hopping, or is it sufficient that the gNB avoid potential error cases by implementation?  Question to All: Please include your view on the FFS points. If possible, we can try to converge in this meeting. |
| Huawei/HiSilicon | We are fine with Proposal 1 and prefer Alt. 1. We also do not think anything needs ob e specifed ob ee potential error cases, they are manageable by the gNB. |
| Nokia, NSB | Agree with the FL proposal #1.  ob ee 1st FFS point, our first preference is Alt-1.  ob ee 2nd FFS point, we prefer to leave this for gNB implementation. |
| OPPO | We agree with Proposal #1.  ob ee 1st FFS, we support Alt-1 due ob e simplest modification in 38.213 Section 9.2.1. Both Alt-2a and Alt-2b need extra specification effort, and the benefit is not clear.  ob ee 2nd FFS, these two potential error cases should be discussed in Section 2.1 and can be left to gNB implementation. |
| Vivo | First, we have the same clarification comment as in Conclusion #1. We’d like to clarify that the discussion is for common PUCCH resoruce sets before dedicated PUCCH resource configuration instead of prior to RRC. Our understanding is that the common PUCCH resource can also be applied after RRC if there’s no dedicated PUCCH resource configuration. So we suggest to revise the wording. **Proposal #1 (PUCCH Resource Set Construction before dedicated PUCCH resource configuration)**  * Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets before dedicated PUCCH resource configuration for multi-RB PUCCH formats 0/1   For FFS point 1, Alt-1 is good enough to guarantee the orthogonality between neighber cells. For FFS point 2, our understanding ob ee this is actually the RB shorage issue related to Conclution #1. |
| Intel | We are OK with the FL’s proposal, but we would rather prefer to discuss first the RB shortage issue, since these are correlated.  As for our preference:   * ob ee 1st FFS, we prefer Alt-1. * ob ee 2nd FFS, we prefer to leave this up to gNB’s implementation |
| InterDigital | We are fine with the proposal. ob ee 1st FFS, we prefer Alt-1. ob ee 2nd FFS, we are fine with leaving this up to gNB implemenation. |
| Qualcomm | As we stated in our contribution, we generally support proposal-1 and support Alt-1 for the first FFS point.  ob ee second FFS, we need clarification about “up to gNB implementation to avoid the following potential error cases” in FFS point 2. ob e means that gNB will use a smaller N\_RB to avoid case 1 and case 2 to occur, we are strongly agaisnt it as it will lead coverage issue and we don’t think we should introduce addtional limitation for N\_RB compared to dedicated PUCCH resource. ob e means that gNB will never schedule a UE to use such a “out of band“ common pucch resource, we are fine with it. UE should not expect ob e scheduled with such a resource and should treat it as error case. In other words, we accept the fact that there are fewer than 16 usable common pucch resource, but we can not accept that common pucch resource uses a smaller N\_RB to make all 16 pucch resource usable.  We think initial cyclic shifts for common pucch resource need to scale up too. A third FFS should be added on if inital CS should be scaled up. As the initial CS for common PUCCH resource also depends on the outcome of item 3. |
| Apple | We are fine with proposal 1 and support Alt 1 on the first FFS.  On case 1 of the second FFS, we prefer that the UE behavior should be specified to not expect this scenario to occur.  On case 2 of the second FFS, would like to clarify what gNB implementation means (a) gNb would not allow the resources to overlap e.g. reduce NRB or (b) gNB can allow the resources to overlap but would prevent same/multple UEs from accessing the resource at the same time ?  On the FH issue, we can accept that this is addressed by gNB implementation. Although there is little to no frequency diversity in this case, on further thought, the gNB may want some repetition gain and most importantly, it does not break the UE implementation in any way. |
| Futurewei | We agree with the Proposal #1.  For the first FFS point, we prefer Alt-1;  For the second FFS point, we see it results from the RB shortage issue. We suggest that if Conclusion #1 is made and the RB shortage issue is not reopened for a separate discussion, it can be handled here within this FFS. |
| CATT | We are OK for alt1. Regarding the scaling, we think N\_RB is the most simple approach. Regarding the error case, we want to leave to gNB implementation. |
| Moderator | There seems to be different understandings on what "up to gNB implementation" means. It was not the moderator's intention that "gNB implementation" would mean that the gNB must configure N\_RB small enough to avoid RB shortage. Rather the intention was that it is up to the gNB to configure N\_RB as it pleases to trade-off PUCCH coverage vs. capacity. Hence, the open question is whether or not the spec explicitly captures the error cases, e.g., using wording such as "the UE does not expect that ..."  Please see updated Proposal #1a to clarify. |

### **Proposal #1a (PUCCH Resource Set Construction Prior to RRC)**

* Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets prior to RRC configuration for multi-RB PUCCH formats 0/1
* As previously agreed, the number of RBs for each PUCCH resource in a set is N\_RB which is signaled in SIB1
* The lowest-indexed RB for each PUCCH resource is a function of N\_RB
* The following example change to 38.213 Section 9.2.1 can be recommended to the editor of 38.213 to use at the editor’s discretion (subject to resolution of the below FFS on the value of X)

---- Start ----

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

---- End ----

* FFS: Supported value of X. Down-select to one of the following alternatives:
  + Alt-1: X = N\_RB
    - Note: This alternative is mathematically equivalent to Example Construction 1 discussed in RAN1#106-e.
  + Alt-2a: X is a fixed value less than N\_RB, e.g., 1, N\_RB / 2, …
  + Alt-2b: X is configurable, e.g., via SIB1
* FFS: Whether or not the spec explicitly captures either or both of the following error cases related to a potential RB shortage issue:
  + Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
  + Case 2: An indicated PUCCH resource with r\_PUCCH ≥ 8 overlaps the RBs of a PUCCH resource with r\_PUCCH < 8.

Please provide your company view on Proposal #1a.

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| --- | --- |
| **Company** | **View/Position** |
| NTT DOCOMO | We support Proposal #1.  For the 1st FFS point, our 1st preference is Alt-2a since it allows to allocate larger number of RBs and may provide better coverage than Alt-1 for initial access while the same user multiplexing capacity as Rel-15 can be kept if it is allowed that PUCCH resources can be overlapped between neighbor cells. Otherwise, i.e., if the orthogonality between PUCCH resources in different cells should be maintained as current specification even for FR2-2 band, we can also support Alt-1 as 2nd preference.  For the 2nd FFS point, we think it should be left to gNB implementation to avoid the error cases. |
| Qualcomm | Thanks for the updated proposal #1a, however, we think clarification is still needed for second FFS:   1. What does it mean when spec “explicitly captures …”? Does it mean sth in the spec that “ such a resource is invalid, and UE is NOT expect to be scheduled with such a resource” or sth like this? We want to understand it a little bit more of it. 2. What does it mean when spec “does not explicitly captures …”? Does it mean “it is up to gNB impmentation”? then again, we want to know what “up to gNB implantation” mean. Does it mean gNB will use smaller N\_RB to make all 16 resources valid?   We still want a third FFS for initial cyclic shift for common pucch resource. |
| vivo | Seems our previous wording suggestion to Proposal #1 is missed. Our understanding is that existing table is for common PUCCH configuration, not just PUCCH prior to RRC.  So we suggest rewording: **Proposal #1a (PUCCH Resource Set Construction before dedicated PUCCH resource configuration)**  * Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets before dedicated PUCCH resource configuration for multi-RB PUCCH formats 0/1 |
| LG Electronics | We support Proposal #1a. Alt-1 is fine but Alt-2b is more preferred considering the different X values can be configured between the gNBs. In the case of the second FFS point, it may be considered to use only valid resources in the frequency domain rather than leaving them to gNB implementation.  Regarding on the scaling value X for PRB offset, FDM (frequency division multiplexing) between cells should be considered when the PRB indices are calculated based on the value of NRB. Since the PRB offset in TS 38.213 Table 9.2.2-1 is defined for a single RB PUCCH format 0/1, there may be overlapping or wasted PRBs when NRB is used to directly calculate PRB indices without considering FDM between PUCCH resources of different cells.  Meanwhile, it may need to discuss whether special handling for the PUCCH resource set index 15 is necessary or not. the PRB offset for PUCCH resource set index 15 is determined by based on the current Table 9.2.1.-1 and 4 FDM resources are required to create 16 resources because the number of initial CS indexes is 4. 16 PUCCH resources may not be obtained when the indicated value of NRB is larger than the since index 15 uses the upper and lower BWP/4 RBs of the BWP as PRB offset and total NRB x 4 RBs are required to obtain 16 resources. |
| Samsung | We are ok with the proposal.  For the first FFS, we support Alt-1. The gain of using other complicated method is not clear. |
| ZTE,Sanechips | For the first FFS, we support Alt-1.  For the second FFS, we think it should be left to gNB implementation. |
| Sony | We are okay with Proposal 1a. Also, we prefer Alt-1 for the first FFS. |

The following was agreed in the GTW on 10/11:

### **Agreement:**

* Reuse the existing Rel-15/16 PUCCH configuration Table 9.2.1-1 in 38.213 for configuration of PUCCH resource sets prior to dedicated PUCCH configuration for multi-RB PUCCH formats 0/1
* As previously agreed, the number of RBs for each PUCCH resource in a set is N\_RB which is signaled in SIB1
* The lowest-indexed RB for each PUCCH resource is a function of N\_RB
* The following example change to 38.213 Section 9.2.1 can be recommended to the editor of 38.213 to use at the editor’s discretion (subject to resolution of the below FFS on the value of X)

---- Start ----

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as , where is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as

If and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as and the lowest PRB index of the PUCCH transmission in the second hop as

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as 

---- End ----

* FFS: Supported value of X. Down-select to one of the following alternatives:
  + Alt-1: X = N\_RB
    - Note: This alternative is mathematically equivalent to Example Construction 1 discussed in RAN1#106-e.
  + Alt-2a: X is a fixed value less than N\_RB, e.g., 1, N\_RB / 2, …
  + Alt-2b: X is configurable, e.g., via SIB1
* FFS: Whether or not the spec explicitly captures either or both of the following error cases related to a potential RB shortage issue:
  + Case 1: Some of the RBs of a PUCCH resource fall outside the initial UL BWP
  + Case 2: An indicated PUCCH resource with r\_PUCCH ≥ 8 overlaps the RBs of a PUCCH resource with r\_PUCCH < 8. PU
* FFS: Whether or not special handling for PUCCH resource set index 15 is necessary.

### 2nd Round Discussion

1st FFS:

In the above agreement, the following is a summary of company views so far on the 1st FFS:

* Alt-1:
  + Huawei, Nokia, OPPO, vivo, Intel, Interdigital, Qualcomm, Apple, Futurewei, CATT, LGE (2nd preference), Samsung, ZTE, Sony, NTT DOCOMO (2nd preference), Transsion
* Alt-2a:
  + NTT DOCOMO (1st preference)
* Alt-2b:
  + LGE (1st preference)

Given that all companies support Alt-1 either as a 1st or 2nd preference, the following is proposed. Would this be acceptable to NTT DOCOMO and LGE, despite it being your 2nd preference?

### **Proposal #1b (Scaling of RB offset)**

* In the RAN1#106bis-e agreement on construction of PUCCH resource sets prior to dedicated PUCCH configuration, the following is supported at least for PUCCH resource set index 0 .. 14 in Table 9.2.1-1:
* FFS: Value of X for PUCCH resource set index 15
* Notes:
  + This is Alt-1 in the agreement
  + Above FFS to be resolved in this meeting (see Question #6 below)

2nd FFS:

The following is a summary of company views so far on the 2nd FFS:

* **Alt-a**: Error cases managed by gNB implementation
  + Huawei, Nokia, OPPO, Intel, Interdigital, CATT, ZTE, Ericsson, Transsion
* **Alt-b**: Error cases explicitly captured in spec
  + Qualcomm, Apple

Regarding Alt-a, as discussed in the GTW, at least from the moderator's point of view "Error cases managed by gNB implementation" has the following meaning:

* Case 1: The gNB would naturally avoid this configuration since it does not make sense to configure a PUCCH resource that steps outside the UE UL BWP
* Case 2: The gNB avoids indicating an r\_PUCCH that would cause an overlap with a PUCCH resource corresponding to a different value of r\_PUCCH since overlap of PUCCH resources amongst users in the same gNB receive beam would lead to poor performance

Regarding Alt-b, the moderator's understanding for proponents who prefer that "Error cases are explicitly captured in spec" would like to explicitly specify something like the following:

* Case 1
  + "For the indicated common PUCCH resource set prior to dedicated PUCCH configuration, the UE does not expect to be indicated with a PUCCH resource that is not fully contained within the initial UL BWP."
* Case 2
  + "For the indicated common PUCCH resource set prior to dedicated PUCCH configuration, the UE does not expect to determine a PUCCH resource index that corresponds to a PUCCH resource in the same set with a different PUCCH resource index."

The moderator points out that there are always error cases in the spec for certain combinations of configured parameters and it is impossible to specify all of them. Is there something special about these particular error cases that warrant explicitl specification?

### **Question #5 Given the above interpretation of the 2nd FFS, do you prefer Alt-a or Alt-b? Please provide a rationale for your view.**

3rd FFS:

LGE provided the the following explanation above regarding the 3rd FFS:

*"Meanwhile, it may need to discuss whether special handling for the PUCCH resource set index 15 is necessary or not. the PRB offset for PUCCH resource set index 15 is determined by based on the current Table 9.2.1.-1 and 4 FDM resources are required to create 16 resources because the number of initial CS indexes is 4. 16 PUCCH resources may not be obtained when the indicated value of NRB is larger than the since index 15 uses the upper and lower BWP/4 RBs of the BWP as PRB offset and total NRB x 4 RBs are required to obtain 16 resources."*

The moderator questions whether or not this case is any different than the error cases discussed in the 2nd FFS?

### **Question #6 Which one of the following alternatives to you prefer? If Alt-y, please comment on what special handling is needed.**

* **Alt-x**: No special handling is required, i.e., for PUCCH resource set index 15 in Proposal #1b.
* **Alt-y**: Special handling is required for PUCCH resource set index 15 in Table 9.2.1

Please provide your view on Proposal #1b, Question #5, and Question #6:

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Intel | * For proposal 1b, we are OK with the proposal. * For Question #5, Alt-a is preferred. * For Question #6, Alt-x is preferred. |
| InterDigital | We are fine with proposal 1b.  For the 2nd FFS, we prefer Alt-a as captured.  For the 3rd FFS, we prefer Alt-x. |
| ZTE, Sanechips | Proposal 1b is ok for us.  Regarding Question #5, we support Alt-a: Error cases managed by gNB implementation.  Regarding Question #6, Alt-x is preferred. |
| NTT DOCOMO | For Proposal #1b, we can accept the proposal if majority supports Alt-1 to ensure the orthogonality between PUCCH resources for different cells as current specification.  For Question #5, our preference is Alt-a. Why this particular error case has to be captured in the specification is unclear.  For Question #6, we support Alt-x. |
| Qualcomm | For proposal 1b, we are fine.  For the 2nd FFS, we would like the moderator to clarify if Alt-a also allow the case of "gNB configures N\_RB such that some PUCCH resources are not fully confined within the initial UL BWP, but the gNB will not use those resources“. If this case is not included, we cannot support Alt-a, as we believe the system should not be forced to scarify coverage when the initial UL BWP is narrow (which also is used to improve coverage). On the other hand, if that case is also included in Alt-a, the only difference between Alt-a and Alt-b is if we need to include "UE does not expect“ language in the spec. Then we can support either Alt-a or Alt-b. But it will be good if these cases are captured in agreement directly to avoid future confusions.  For Question 6, we prefer Alt-x |
| Huawei, HiSilicon | We are fine with Proposal #1b, Alt-a and Alt-x. |
| Transsion | Regarding proposal 1b, we are fine with it.  Regarding Question #5, we prefer Alt-a.  Regarding Question #6, we prefer Alt-x. |
| OPPO | We are OK with Proposal #1b.  For Question #5, we prefer Alt-a. The network can select an appropriate PUCCH bandwidth or schedule a suitable PUCCH resource index to avoid the error cases above, which can be left to gNB implementation.  For Question #6, we prefer Alt-x. |
| LG Electronics | Regarding proposal 1b, we would like to elaborate on the motivation of **Alt-2b** since it is important to consider the PRB offset and FDM (frequency division multiplexing) between cells.  Since the PRB offset in TS 38.213 Table 9.2.2-1 is defined for a single RB PUCCH format 0/1, there may be overlapping or wasted PRBs when NRB is used to directly calculate PRB indices without considering FDM between PUCCH resources of different cells. For example, two cells Cell#1 and Cell#2 can configure the PUCCH resource set to index 1 and 2 in TS 38.213 Table 9.2.1-1, respectively, that are FDMed by PRB offset with 3 PRBs when a single-RB allocation is used for PUCCH resource. If the value of 8 and 6 is indicated as NRB to Cell#1 and Cell#2, respectively, and the PRB index is simply scaled to the NRB, the PRB used by the last PUCCH resource of Cell #1 and the first PUCCH resource of Cell #2 may overlap.Therefore, it is necessary to consider a separate parameter X (coul be different from NRB) for calculating PRB offset considering the FDM between cells to calculate the PRB indices.  **We can accept Alt-1 if X=NRB applies equally to all cells. However, if NRB value different for each cell can be configured, the additional values other than NRB can be left to FFS for further discussion.**  For Question #6, as provided the explanation by Moderator, it may be required the special handling for PUCCH resource set index 15. To explain Index 15 in more detail to illustrate the need for special handling, for Index 15, each BWP/4 PRBs located at low and high frequencies of BWP is used as a PRB offset for index 15, as shown in the figure below.  cid:image035.png@01D7C052.A3429520  The 4 FDMed PUCCH resources are required to obtain 16 PUCCH resources for index 15 since the number of set of initial CS indexs is 4. Therefore, at least NRB x 4 RBs are required to obtain 16 PUCCH resources.  In addition, if the agreed CR is applied directly to index 15 for the calculation of the PRB index, there is no PRB for PUCCH resources in the BWP if a value other than 1 is used as the NRB value. For example, when NRB=2 as shown in the figure below, all RBs of the BWP are used only with the PRB offset value, so there is no RB left for the PUCCH resource.  cid:image036.png@01D7C052.A3429520  For Question #5, Alt-b is preferred but we share the same view with Qualcomm. It will be good to capture in agreement directly to avoid future confusion and it should be included "UE does not expect“ language in the spec. |
| Lenovo, Motorola Mobility | We are fine with proposal 1b  Regarding Question #5, we prefer Alt-a  Regarding Question #6, we prefer Alt-x |
| Nokia, NSB | P1b: We support the proposal  Q#5: We prefer Alt-a  Q#6: We prefer Alt-x |
| Apple | We support proposal 1b  On Q#5, although it does not have to be explicitly captured in the spec, it would be good if the language is caputured formally e.g. in the spec or as a conclusion in the Chairman’s notes so that there is no opportunity for misunderstandings in the future that could require a CR.  Q#6: we prefer Alt-x. |
| Samsung | We support proposal 1b  For Q#5, we support Alt-a. Not all the error cases need to be included in the specification, especially for those easiliy resolved by implementation. If companies still have concerns, we are ok with a RAN1 conclusion to guide the implementation, but no specification impact is needed.  For Q#6, we support Alt-x. |
| vivo | For proposal 1b, we are OK with the proposal.  For Question #5, Alt-a is preferred.  For Question #6, Alt-x is preferred. |
| Moderator | Proposal #1b   * Support   + Intel, Interdigital, ZTE, NTT DOCOMO, Qualcomm, Huawei, Transsion, OPPO, Lenovo, Nokia, Apple, Samsung, LGE (at least if network configures the same N\_RB for all cells), vivo * Support, but with FFS on X for the case that the network configures different N\_RB for different cells   + LGE   Question #6   * Alt-x   + Intel, Interdigital, ZTE, NTT DOCOMO, Qualcomm, Huawei, Transsion, OPPO, Alt-x, Nokia, Apple, Samsung, vivo * Alt-y   + LGE   All but one company support Proposal #1b in which the FFS is resolved to also support X=N\_RB for PUCCH resource set index 15. LGE has expressed two concerns:   * Concern 1 (related to Proposal #1b)   + The concern is that if different cells configure a different value of N\_RB it can happen that PUCCH resources of one value collide with PUCCH resources of another cell.   + The moderator points out that this can happen also in Rel-15 if the network decides to configure the same PUCCH resource set index for different cells. This is a network issue, and does not affect UE behavior. Clearly, it can have a network performance impact if the cells are not isolated; however, that is not the UEs concern. This would be a poor deployment. We do not normally specify gNB behavior, therefore from the moderator's perspective it is unreasonable to put a condition that the network must configure all cells with the same N\_RB. What about cells that don't interfere with each other (isolated)? * Concern 2 (related to Question #6)   + The concern is that if X = N\_RB for PUCCH resource set index 15 and if N\_RB is configured to be greater than 1, the text proposal will not work. LGE states "…all RBs of the BWP are used only with the PRB offset value, so there is no RB left for the PUCCH resource"   + The moderator agrees with LGE that indeed PUCCH resourset set index 15 is not a useful configuration for the case of N\_RB > 1. Indeed, it can happen that certain values of r\_PUCCH, the PUCCH resources will overlap PUCCH resources with other values of r\_PUCCH (same as Case 2) and the frequency hopping will not follow the same pattern as Rel-15. However, the moderator found that r\_PUCCH = 0,1,2,3 will still work (albeit with 0 frequency hopping distance).   + Clearly, the gNB should avoid using a configuration (e.g., row 15) if PUCCH resources within the same gNB receive beam that overlap since that will lead to poor performance. This is the same as Case 2 in Question #5. Hence it seems that there does not need to be special handling.   @LGE: With the above explanations, can LGE compromise and accept Proposal #1c below?  Question #5   * Alt-a   + Intel, Interdigital, NTT DOCOMO, Qualcomm (error case(s) captured as a conclusion), Huawei, OPPO, LGE (if error case(s) captured as a conclusion), Apple (if error case(s) captured as a conclusion), Samsung, vivo * Alt-b   + Qualcomm, LGE   It seems that all companies either support or can compromise to Alt-a, i.e., "Error cases managed by gNB implementation." The companies expressing compromise wish to capture a conclusion for error cases, and this seems reasonable in order to establish common understanding and avoid future confusions and CRs in the maintenance phase.  To answer Qualcomm's question, it is the moderator's understanding that if the gNB wishes to maximize coverage by choosing a large N\_RB value, it should not be restricted to do. If, for certain values of r\_PUCCH, the PUCCH resource is not fully contained within the initial UL BWP, clearly the gNB should avoid indicating such an r\_PUCCH value to the UE.  On further thinking about what error cases need to be captured, the only thing that matters from a UE point of view is that if an indicated r\_PUCCH value results in the PUCCH resource not being fully contained within the UL BWP. Certainly the UE should not be expected to handle this case. Regarding whether or not two different PUCCH resources corresponding to different values of r\_PUCCH overlap, that does not matter at all to the UE. If the gNB indicated these two resources to two UEs, that would be the gNB's fault and the result would be poor performance. However, it would not affect the UE behavior.  @Qualcomm, LGE, Apple: With the above explanations, can you compromise and accept Conclusion #3 below? |

### **Proposal #1c (Scaling of RB offset)**

* In the RAN1#106bis-e agreement on construction of PUCCH resource sets prior to dedicated PUCCH configuration, the following is supported for all PUCCH resource set indices 0 .. 15 in Table 9.2.1-1:
* Note: This is Alt-1 in the agreement

### **Conclusion #3 (Error cases)**

* For a common PUCCH resource set prior to dedicated PUCCH resource configuration, the UE does not expect to determine a value of r\_PUCCH for which the corresponding PUCCH resource is not fully contained within the initial UL BWP
* It is left to gNB implementation to avoid such an error case, i.e., this is not explicitly captured in specifications

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| **Company** | **View/Position** |
| Qualcomm | We are fine with #1C.  For Conclusion #3, there can be some confusion on what “determine” means. We would like to clarify the “determine” is using the PRI received. We suggest to update it as follows: **Conclusion #3 (Error cases)**  * For a common PUCCH resource set prior to dedicated PUCCH resource configuration, for some values of r\_PUCCH, the corresponding PUCCH resource may not be fully contained within the initial UL BWP. The UE does not expect to receive a PRI and determine a value of r\_PUCCH for which the corresponding PUCCH resource is not fully contained within the initial UL BWP * It is left to gNB implementation to avoid such an error case, i.e., this is not explicitly captured in specifications |
| LG Electronics | As above mentioned, we can accept Alt-1 if X=NRB applies equally to all cells. However, we think that the FFS on PUCCH resource set index 15 should be kept for further discussion.  @Steve: Could you capture the below FFS on Proposal #1c?   * FFS: Whether or not special handling for PUCCH resource set index 15 is necessary.   For conclusion #3, we support the modification by Qualcomm. |
| Futurewei | We support Proposal #1c and the modification by Qualcomm for Conclusion #3. |
| ZTE, Sanechips | We are fine with Proposal 1#c and prefer the modified conclusion#3 raised by Qualcomm. |
| Lenovo, Motorola Mobility | We support Proposal #1c and fine with the modification sugessted by Qualcom for conclusion #3 |
| Sony | We support Proposal #1c. We also support Conclusion #3 with QC’s clarification. |

# 3 Cyclic Shift Definition for PF0/1

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Qualcomm [17] | As multi-RB PF0 is extended to a longer base sequence length, for the cyclic shift varying as a function of the symbol and slot number, Eq. 1 should be updated to following Eq.2 where M is the number of RBs occupied by the PUCCH. Note that for multi-RB PUCCH format 0 on FR2-2, as it is contiguous RB assignment, =0.  Eq. 2  In following sub-sections, we like to present our views on for PF0 and for PF0/1 on FR2-2.  **Proposal 1: for a M-RB PF0, information bearing Cyclic shifts are chosen as below:**   * **For 1-bit A/N, use {0, 6}\*M** * **For 2-bit A/N, use {0, 3, 6, 9}\*M** * **For 1-bit A/N + SR, use {0, 3, 6, 9}\*M** * **For 2-bit A/N + SR, use {0, 1, 3, 4, 6, 7, 9, 10}\*M**   **Proposal 2: for a M-RB PF0/1, value range of initial Cyclic shifts should be extended with one of following options:**   * **Option 1: extend it to [0, 1, … , 12M-1].** * **Option 2: extend it to [0, 1, … , 10, 11]\*M**   **Proposal 5: For a common PUCCH resource M-RB PF 0/1, the UE determines the initial cyclic shift index where is the i-th CS index from the set of initial CS indexes, and *i* is determined as for and as for .** |
| vivo [5] | **Proposal 2：For a single sequence of length equal to the total number of mapped REs of the PUCCH resource, the cyclic shift should be adapted with the length of the sequence.**  However, for a single long sequence with all RE mapped within a PRB, the cyclic shift should be additionally dependent on the number of PRBs like formula 2. Meanwhile, the value of and should also depend on the For example, the sequence length is 24 when the PRB number is 2. The value range of should be 0～23 for dedicated PUCCH resources, the candidate values of for common PUCCH resource in Table 1-1 and the candidate values of in Table 1-2 to Table 1-5 should all multiply by 2.  ---Formula 2  Table 1 Copy of Table 9.2.1-1 and Table 9.2.3-3&4 and Table 9.2.5-1&2 from TS 38.213[4]  **Table 1**-1 Copy of Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Index | PUCCH format | First symbol | Number of symbols | PRB offset | Set of initial CS indexes | | 0 | 0 | 12 | 2 | 0 | {0, 3} | | 1 | 0 | 12 | 2 | 0 | {0, 4, 8} | | 2 | 0 | 12 | 2 | 3 | {0, 4, 8} | | 3 | 1 | 10 | 4 | 0 | {0, 6} | | 4 | 1 | 10 | 4 | 0 | {0, 3, 6, 9} | | 5 | 1 | 10 | 4 | 2 | {0, 3, 6, 9} | | 6 | 1 | 10 | 4 | 4 | {0, 3, 6, 9} | | 7 | 1 | 4 | 10 | 0 | {0, 6} | | 8 | 1 | 4 | 10 | 0 | {0, 3, 6, 9} | | 9 | 1 | 4 | 10 | 2 | {0, 3, 6, 9} | | 10 | 1 | 4 | 10 | 4 | {0, 3, 6, 9} | | 11 | 1 | 0 | 14 | 0 | {0, 6} | | 12 | 1 | 0 | 14 | 0 | {0, 3, 6, 9} | | 13 | 1 | 0 | 14 | 2 | {0, 3, 6, 9} | | 14 | 1 | 0 | 14 | 4 | {0, 3, 6, 9} | | 15 | 1 | 0 | 14 |  | {0, 3, 6, 9} |   **Table 1**-2 Copy of Table 9.2.3-3: Mapping of values for one HARQ-ACK information bit to sequences for PUCCH format 0   |  |  |  | | --- | --- | --- | | HARQ-ACK Value | 0 | 1 | | Sequence cyclic shift |  |  |   **Table 1**-3 Copy of Table 9.2.3-4: Mapping of values for two HARQ-ACK information bits to sequences for PUCCH format 0   |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | Sequence cyclic shift |  |  |  |  |   **Table 1**-4 Copy of Table 9.2.5-1: Mapping of values for one HARQ-ACK information bit and positive SR to sequences for PUCCH format 0   |  |  |  | | --- | --- | --- | | HARQ-ACK Value | 0 | 1 | | Sequence cyclic shift |  |  |   **Table 1**-5 Copy of Table 9.2.5-2: Mapping of values for two HARQ-ACK information bits and positive SR to sequences for PUCCH format 0   |  |  |  |  |  | | --- | --- | --- | --- | --- | | HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} | | Sequence cyclic shift |  |  |  |  | |

### Summary of Cyclic Shift Definition for PF0/1

Two companies have proposed that the cyclic shift definition for PF0/1 should be modified to take into account the length of the sequence for multi-RB PUCCH.

The moderator would like to point out that this seems to conflict with the highlighted part of the following agreement:

Agreement:

For enhanced PF0/1 support a single sequence of length equal to the total number of mapped Res of of the PUCCH resource is used. Cyclic shifts for PF0/1 are defined in the same way as Rel-16 for the case that *useInterlacePUCCH-PUSCH* is not configured.

* Note: this is Alt-1 from the RAN1#104 agreement

The moderator's understanding of this agreement is that by using the cyclic shift definition in Rel-16, two PUCCH resources using different cyclic shifts will be orthogonal on a per-PRB basis. It is not clear why the cyclic shift should be redefined accounting for the full sequence length, and if there would be a benefit of doing so. Can there be a performance degradation due to channel variation over the full sequence length? With the Rel-16 definition, the channel variation is expected to be much less over 1 PRB than over the full sequence length.

### **Question #1: Is it sufficient to reuse the Rel-16 cyclic shift defintition for enhanced (multi-RB) PF0/1 (as previously agreed), or is there a need/benefit of redefining the cyclic shift accounting for the full base sequence length over multiple RBs as proposed in [5],[17]?**

Please provide your view on Question #1.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Huawei/HiSilicon | As pointed out, it is already agreed to re-use the cyclic shifts from Rel-16. The DFT of   with is a cyclically shifted version of the DFT due to . That solution applies for any sequence length which is a multiple of and it produces 12 equally spaced cyclic shifts. We see no reason to change the agreement. |
| Nokia, NSB | It is sufficient to use the Rel-16 mechanism |
| OPPO | It is sufficient to reuse the Rel-16 definition. |
| vivo | We don’t think the cyclic shift updated with the number of RBs violates the Rel-16 defination. In Rel-15/16, the equels to the sequence length for PF 0/1 without interlace; so the user multiplexing capacity is 6 or 3 for PF 0 when UCI payload is 1 bit or 2 bits. However, when the PUCCH occupies N\_RB RBs with a single long sequence, the sequence length is 12\*N\_RB. There are at most 12\*N\_RB sequences can be used for user multiplexing. If the fomula does not include N\_RB, the user multiplexing capacity is at most 12 due to the characteristic of ZC-sequence.  So our proposal (i.e. update the cyclic shift with the sequence length) actually follows the existing Rel-15/16 way. |
| Intel | We agree with HW’s and other companies view, and we also do not see any technical reason to change the agreeement. |
| InterDgitial | We agree that the Rel-16 definition should be enough. |
| Qualcomm | We share the view with vivio and also think there is no conflict with the previous agreement as in Rel-16, PUCCH 0 is still using base sequence 12 which is equal to the number of REs per RB. When the base sequence length is extended to 12\*M, 12 should be replaced with 12M and corresponding scaling up m\_0 and m\_cs.  This proposal is to inherite the design principle of Rel-15 PF0. By scaling up both m\_cs and m\_0, to maintain at least the SAME (not better) level of multiplexing capability with regard to the ratio between total number of cyclic shifts and number of CS used per UE. |
| Apple | We think that the Rel-16 mechanism is sufficient. |
| Futurewei | It is ok to use a mechanism that does not conflict with the Rel-16 definition. |
| CATT | It is sufficient to use the Rel-16 mechanism |
| NTT DOCOMO | We think Rel-16 definition is sufficient as previously agreed. |
| LG Electronics | We think that the Rel-16 cyclic shift definition for enhanced PF0/1 is sufficient since the value range of cyclic shift for DM-RS in PUSCH is not varied based on the number of RBs. |
| Samsung | We understand the concern on the confusing wording the agreement, but we believe reusing the cyclic shift from Rel-16 definition is sufficient. |
| ZTE, Sanechips | We think that it is sufficient to reuse the rel-16 cyclic shift definition for enhanced(multi-RB) PF0/1(as previously agreed). |
| Lenovo, Motorola Mobility | We see that reusing Rel-16 definition for multi-RB PF0/1 is sufficient |
| Moderator | Conclusion #2 below was discussed during the GTW on 10/11. It has not yet been agreed, since companies wanted more time to check. It is captured in the Chairman Notes as "Proposed Conclusion" for now, so we should try to resolve this issue during this meeting.  Please continue to discuss below. |

### **Conclusion #2 (Cyclic Shift Definition for PF0/1)**

* For enhanced (multi-RB) PF0/1, cyclic shifts are defined in the same way as Rel-16 for the case that *useInterlacePUCCH-PUSCH* is not configured, i.e., based on a set of cyclic shifts. The formula for is not a function of .

Please provide your company view on Conclusion #2

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Intel | We support conclusion #2, and we do not see any technical reason to deviate from it. We have same understanding as the moderator, that by changing the formula for to factor in account, this may lead to potential loss in orthogonality. Also we are not clear what is the benefit of scaling the cyclic shifts by. With that said, we are actually very concerned that we are spending time discussing such a topic, when there are other issues that have been technically very well motivated and supported by through studies. |
| InterDigital | We support conclusion #2. |
| ZTE,Sanechips | We support conclusion #2 and agree with the reason provided by Intel. |
| NTT DOCOMO | We support Conclusion #2. For the proposed modification of CS, we would like to clarify the benefit. If the benefit is improvement of user multiplexing capacity by extending available cyclic shift index, it cannotbe discussed further according to the previous agreement. |
| Huawei, HiSilicon | We support Conclusion #2. The existing formula produces 12 equidistant cyclic shifts and nothing needs to be changed. |
| Transsion | We support conclusion #2. |
| OPPO | We support conclusion #2. User multiplexing capacity has already been agreed to be considered with lower priority. |
| LG Electronics | We support Conclusion #2. |
| Lenovo, Motorola Mobility | We support Conclusion #2 |
| Nokia, NSB | We support conclusion #2 |
| Apple | We are fine with conclusion #2 |
| Samsung | We support conclusion #2 |
| vivo | Response to Huawei’s comment:  For legacy R15/16 cyclic shift, the value of is {0,1,2,3,4,5,6,7,8,9,10,11}, there are at most 6 users can be multiplexed using different cyclic shifts when UCI payload is 1 bit for PF0.  For a single long sequence PUCCH with N\_RB RBs, if the cyclic shift varies as a function of N\_RB and the m0 and m\_cs is also related to N\_RB as we proposed. When the UCI payload is 1 bit for PF0 and N\_RB is 2, the candidate value of m0 is {0,1,2…23}, the candidate value of is {0,1,2…23}. So there can be at most 12 users multiplexed using different cyclic shifts when UCI payload is 1 bit for PF0. Therefore, this improves user multiplexing capacity compared to the legacy one.   |  |  | | --- | --- | | The set of cyclic shifts | | | The legacy | Our proposal | |  |  |   Response to moderator and Intel’s comment:  It was stated that our proposal lead to “potential loss in orthogonality”. So we investigated correlation of sequence compareing legacy and our proposed cyclic shift way. The following figure shows for N\_RB=2, the orthogonality has no difference when *m* is 12 (legacy) or 24 (proposed cyclic shift way). In our evaluation, u=0, and v=0, N\_RB is 2 for the base sequence. m is 0 for sequence 1, and the value of m varies from 0 to 23 for sequence 2 which is the abscissa. The peak value 1 is the autocorrelation coefficient, and the cross-correlation coefficient is almost zero.    Given it’s agreed to use a single sequence of length equal to the total number of mapped REs of the PUCCH resource, keeping the legacy cyclic shift actually is not fully utilizing the potential benefit of the long sequence when N\_RB >1. Considering the identified small specification impact, we feel this proposal is a low hanging fruit which inherits Rel-15/16 design principle and goes along with previous agreement of single sequence. |
| Moderator | * Support Conclusion #2   + Intel, Interdigital, ZTE, NTT DOCOMO, Huawei, Transsion, OPPO, LGE, Lenovo, Nokia, Apple, Samsung * Do not support Conclusion #2   + vivo   All but one company prefer to avoid making changes to the cyclic chift definition for PF0/1, i.e., resuse the current Rel-16 spec. vivo prefers to modify the cyclic shift definition to account for the number of RBs for the purposes of increasing user multiplexing capability. Two companies point out enhancements related to increasing user multiplexing has been previously agreed to have low priority.  Clearly consensus is required to make changes to the spec, and so far there is no consensus. The moderator's recommendation is to leave this issue open, but only until the end of this meeting. If there is no consensus is achieved by the end of the meeting, the issue should be closed to avoid spending time on an issue with little chance of consensus.  FL recommendation: Continue to discuss until end of this meeting, but if no consensus is achieved then Conclusion #2 should be agreed. |
| Futurewei | We support Conclusion #2 and agree that the remaining time should be spent on issues that can possibly reach consensus. |
| ZTE, Sanechips | We maintain our original view and support Conclusion #2. In the final stage, we think it would be better to focus on the some issue with high priority. |
| Lenovo, Motorola Mobility | We support conclusion #2 and agree with moderator’s recommendation |
| Sony | We support the moderator’s recommendation. |

# 4 Potential Coverage Imbalance between PF2/3 and PF4

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Futurewei [3] | ***Observation 3. One remaining concern is that whether PF2/3 is expected to deliver a satisfactory coverage performance, especially for PF3 when more than 115 bits are associated, even if it uses 16 as the maximum number of RBs, given that it has not been studied in this agenda.***  ***Proposal 3. It is more reasonable that the UCI payload limit is not restricted for enhanced PF4 in case the unenhanced PF3 turns out not being capable of delivering good coverage when 16 RBs is used for FR2-2*** |
| OPPO [6] | **Proposal 4: For PF2/3, the actual number of RBs used for a PUCCH transmission is equal to NRB, i.e., the actual number of RBs does not vary dynamically based on PUCCH payload.** |

### Summary of Potential Coverage Imbalance

Two companies have proposed modifications to address a potential coverage imbalance between PF2/3 and PF4. While PF2/3 supports large payloads and multiple RBs (up to 16), the number of RBs varies dynamically with the payload. In contrast, for enhanced (multi-RB) PF4, the payload is restricted to a maximum of 115 bits (as concluded last meeting) and the number of RBs (up to 16) does not vary dynamically with the PUCCH payload (as agreed in RAN1#104-e). Hence, the concern is that if the PUCCH payload is larger than 115 bits, and one is forced to use PF2/3, the coverage may not be optimized since the actual number of RBs may be less than the configured value.

Conclusion:

For enhanced (multi-RB) PF4, maintain the same maximum UCI payload limit as in Rel-15/16 (115 bits).

Agreement:

* The configured number of RBs for enhanced PF 0/1/4 is denoted NRB
  + The minimum value of NRB is 1 for PF 0/1/4 for all subcarrier spacings
  + The maximum value of NRB depends on subcarrier spacing
    - FFS: maximum value for each SCS and each of PF0/1/4
  + FFS: Allowed values of NRB within the [min/max] range
  + FFS: Details of indication of NRB by cell-specific (for PF0/1) and dedicated signaling (PF0/1/4)
  + FFS: Whether or not multiplexing of users with misaligned RB allocations is supported, where "misaligned" also includes users with different # of RBs.
  + For PF4:
    - The actual number of RBs used for a PUCCH transmission is equal to NRB, i.e., the actual number of RBs does not vary dynamically based on PUCCH payload
    - NRB fulfils the following: where is a set of non-negative integers
* Note: if frequency hopping is enabled, NRB is the number of RBs per hop
* Note: decisions on the maximum value of NRB for each SCS and PUCCH format shall take into account link budgets based at least on the agreed evaluation assumptions

One company [3] proposes to increase the maximum PUCCH payload for PF4 to be larger than 115 bits. Another company [6] proposes to enhance PF2/3 such that the number of RBs does not vary dynamically with the PUCCH payload.

The moderator observes that PF2/3 enhancements are not in scope according to the WID; however, the moderator questions whether or not by gNB implementation, the maximum coding rate for PF2/3 could be configured low enough to ensure that 16 PRBs are used, thus alleviating coverage concerns? The proposal to increase the maximum payload size for PF4 is certainly in scope; however, it would revert the conclusion from the prior meeting. As always, if there is consensus to do so, we could try for a new agreement.

### **Question #2: Do you agree that there is a potential coverage imbalance issue between PF2/3 and enhanced (multi-RB) PF4, and if so, should this be addressed?**

Please provide your view on Question #2.

|  |  |  |
| --- | --- | --- |
| **Company** | **View/Position** | |
| Huawei/HiSilicon | We have raised the issue with the PF4 payload limit in previous meeting. It may unnecessarily restrict the usability of this format and increasing the payload could be a potential alternative. | |
| Nokia, NSB | We see that the already agreed configurability provides enough flexibility for ensuring sufficient coverage. | |
| OPPO | The potential coverage imbalance issue between PF2/3 and enhanced PF4 has already been shown in our simulation results, so it should be addressed. Furthermore, we find that it can’t be handled by gNB implementation. For example, for PF3, even if the lowest code rate, i.e. r=0.08, and Qm=1 are configured, the PUCCH resource configured for a UE can carry bits. If the number of UCI bits is 120, the number of RBs used for PF3 transmission will be decreased to 11 according to 38.213 Section 9.2.3. Therefore, in 60GHz unlicensed band, the coverage performance of PF3 may be degraded. This is why we proposed a similar conclusion with PF4 can be made for PF2/3. | |
| vivo | First of all, PF2/3 enhancement is not in the WI scope, so we don’t think it needs to be addressed.  Regarding PF4 payload limit, we don’t agree to revert the conclusion from last meeting. |
| Intel | We would like to follow the conclusion made, and we do not think that additional flexibility is needed. | |
| InterDigital | We don’t see any issues on the potentail coverage imbalance issue, so we don’t see the need to address it. | |
| Qualcomm | We agree with Nokia | |
| Apple | We agree with Vivo and do not see a need to make any changes | |
| Futurewei | We can see the benefit of effort beyond the conclusion for avoiding a potential coverage imbalance issue, while we agree that it is up to the group consensus for whether to try with effort. | |
| CATT | We don’t see any issues on the potentail coverage imbalance issue | |
| NTT DOCOMO | We agree that the coverage for PF2/3 may not be optimized depending on the number of RBs for PF4 and/or payload size. However, we think the required number of RB can be configured for PF2/3 by configuration of the maximum code rate for PF2/3 and enhancements for PF2/3 are out of scope according to WID as moderator mentioned. In addition, if the agreement highlighted above is revisited, the rate matching scheme for PF4 with multi-PRB which has been agreed previously also should be revisited since it has been agreed considering the agreement above. Thus we don’t think this issue should be discussed further. | |
| LG Electronics | We agree to address a potential imbalance issue between PF2/3 but do not agree to address enhanced (multi-RB) PF4 because the objective is to increase coverage for PF4, and that PF3 can be used for larger payloads.  For PF2/3, the lower bound of the number of RBs for PF2/3 can be configured considering the potential coverage imbalance. The actual number of RBs for PF2/3 does not fall below the configured lower bound even if it varies dynamically based on the PUCCH payload. | |
| Samusng | We believe current agreements already support a functional freature, and further enhancement on the balance of coverage of different PUCCH formats may not be essential at this stage, and this topic can be deprioritized. | |
| ZTE, Sanechips | We think we should firstly answer the question on whether the coverage performance can be guaranteed or not by increasing the maximum payload size for PF4. If the answer is no, then maybe increasing N\_RB and maximum payload size is a more effective way. However more simulations are needed to confirm such questions, and due to the limit time of this WID, We suggest deprioritizing this topic. | |
| Lenovo, Motorola Mobility | We dont see a need to address PF2/3 enhancement since it is not in the scope of this WI | |
| Transsion | We don’ t see the necessity to enhance the PF2/3 which is out of the WI scope. | |
| Moderator | Companies views are mixed. Some companies do not see an issue with coverage imbalance. Many companies view that the current agreements support a functional feature and prefer not to revisit prior agreements. Some companies which to revisit the conclusion on the maximum payload for PF4 if there is consensus to do so. Several companies point out that changes to PF2/3 are out of scope for this WI.  From the moderator's point of view, the only viable option is to re-visit the conclusion on the maximum payload size for enhanced (multi-RB) PF4. However, there is not consensus to do so.  FL Recommendation: De-prioritize this issue due to lack of consensus. | |

# 5 Potential Assistance Info Provided to gNB

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Intel [11] | **Observation 3: If the gNB is not aware of the correct UE’s transmit beamforming gain, by using a pessimistic approach and assuming that the UE’s transmit beamforming gain is 0 dBi, the gNB may configure up to more than 5 times the number of PRBs that would be otherwise needed.**  **Proposal 5: RAN1 should discuss a proper framework to implicitly or explicitly indicate the UE’s beamforming gain to the gNB.** |
| CATT [7] | 1. For RRC connected UEs, it is beneficial to update the number of RBs with the change of PUCCH transmission power.   **Proposal 1 For RRC connected UEs, a PHR for PUCCH can be introduced to help gNB to calculate the number of RBs.**  **Proposal 2 For initial accessed UEs, information could be reported in MSG3 to help gNB to determine the number of RBs.** |

### Summary of Potential Assistance Information Provided to gNB

Two companies have proposed to support provision of assistance information to the gNB such that could potentially help for configurating an appropriate number of RBs for PF0/1/4. In [11], the assistance information is an indication of the UE's tranmit beamforming gain (the TxBF quantity used in prior evaluations of MIL). In [7], the assistance information is in the form of a power headroom (PHR) report for PUCCH.

### **Question #3: Do you agree that it is needed/beneficial to provide some form of assistance information to the gNB to aid in configuration of the number of RBs for PUCCH?**

Please provide your company view on Question #3.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Huawei/HiSilicon | We currently do not see that such information is needed. Whether it is beneficial is another thing. We typically require a lot of benefits from enhancements that involve new signalling, and until that has been shown, we remain negative to this. |
| Nokia, NSB | We view this as an optimization. Given the late stage in the WI and a large number of open issues especially in other sub-AIs, we prefer not to define further assistance information. |
| OPPO | We agree with Huawei. |
| vivo | We also see this as some type of optimization.  We’re open to discuss UE reporting for the configuration of the numbe of RBs for PUCCH if time permits. |
| Intel | As for whether gNB‘s assistance is needed or not, we would like to highlight a few point:   * As companies have noticed, there is a large dependency between the number of PRbs required by a UE to achieve a specific MIL and the UE’s transmit beamforming gain, which is unknown by the gNB. * Based on our evaluation, when there is a mistmatch between the gNB’s assumption on UE’s transmit beamforming gain and the actual UE’s capability, this would lead to a big loss in terms to MIL, and this loss could be quite substaintial if the gNB assumes a much larger UE’s transmit beamforming gain (e.g., 6dB) than the real UE’s transmit beamforming gain (e.g., 0 dB).   In the figure below, as an exampe it is shown the achievable MIL performance at 120 kHz SCS when the UE’s TxBF is the same as that assumed by the gNB (transparent bars) and achievable MIL performance when the UE’s TxBF is different than what assumed by the gNB.  Chart  Description automatically generated  For certain UE EIRP and UE’s output power, **the MIL loss is ~5dB**.   * While it could be argued that a gNB could potentially take always a pessimistic approach and assume the UE’s beamforming gain is 0 dBi, this will come at the cost of a very inefficient spectrum utilization with reduce multiplexing capability, especially since it is quite likely that UEs may employ directional transmissions which require/utilize much higher beamforming gains, whose effectively require much smaller number of PRBs to achieve same coverage. In this matter, the Table below shows the number of PRBs that may need to be configured to achieve maximum MIL when the beamforming gain is 0dBi (first value in black) or 6dBi (second value in red) for different values of UEs EIRP and output power.     The table highlights that by using a pessimistic approach the impact in terms of spectrum efficiency may be quite large, and **a UE may be configure to use up to more than 5 times the number of PRBs that may require**.  With that said, we think that gNB’s assistance regarding the UE’s transmit beamforming gain is needed, and may not be regarded as an optimization considering the loss that a UE/the system may be incurring into |
| InterDigital | We don’t see a need of the assistance information yet. |
| Qualcomm | We think it is beneficial to provide such information, but we doubt we have time to fully discuss it given only two meetings left for this WI |
| Apple | We see the benefit that this information (from Intel’s analysis). We would be open to this if there is enough time to do so. |
| CATT | We prefer to de-prioritize this issue. |
| NTT DOCOMO | Given the limited time for Rel-17 completion and that it is not essential, we believe it should be at least deprioritized. We current do not see the significant need of such UE assistance. |
| LG Electronics | We agree with Huawei and it seems optimization issue that to provide some form of assistance information |
| Samusng | We believe current agreements already support a functional freature, and further enhancement on the assistant information may not be essential at this stage, and this topic can be deprioritized. |
| ZTE, Sanechips | We think there is no need to report such assistance information to the gNB. |
| Lenovo, Motorola Mobility | We think this topic can be de-prioritized at this stage |
| Transsion | Such information is beneficial for gNB to properly configure the number of RBs for PUCCH. Hence, we are open to discuss it. |
| Moderator | Some companies view that assistance information could be useful, while others do not see a strong motivation. Many companies view is that this issue should be de-prioritized due to little remaining time in the WI.  FL Recommendaton: De-prioritize this issue |
|  |  |
|  |  |
|  |  |
|  |  |

# 6 PUCCH Power Control

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| CATT [7] | **Observation 2 PUCCH power control is based on the maximum transmission power of the user equipment, which only depends on the user's capability.**  **Proposal 5 It is needed to modify the maximum transmission power in the PUCCH power control formula for different configured number of RBs.**  In R16, PUCCH power control is related to the maximum transmission power of the user, which only depends on the user's capability. However, for 52.6GHz~71GHz, the transmission power limit is also variable when the number of RB is variable. So the maximum transmission power for different RB number will also change accordingly. If the maximum power for different RB configurations is the same, the transmitted power on each RB may be higher than the PSD limit. So it is needed to modify the PUCCH power control formula. For 52.6GHz~71GHz, the formula may change as below:  where  - is the UE maximum output power for the configured number of RBs for a PUCCH resource  -  is the maximum output power defined in [8-1, TS 38.101-1], [8-2, TS38.101-2] and [8-3, TS38.101-3] for carrier  of primary cell  in PUCCH transmission occasion  - is calculated by the PSD limit and the configured number of RBs for a PUCCH resource. The PSD is defined for 1 RB power limit. |

### **Summary of PUCCH Power Control**

One company has raised a potential issue regarding the PUCCH power control formula. In [7] it is proposed to alter the formula to account for multiple RBs and a potential PSD limit. The moderator observes that PSD limits are not relevant in all regulatory regions.

### **Question #4: Do you agree that it is needed to modify the PUCCH power control formula in 38.213 Section 7.2 in order to account for multiple RBs and a potential regulatory PSD limit as described in [7]?**

Please provide your company view on Question #4.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Huawei/HiSilicon | This issue may need further discussion, it seems to be a major change for the power control functionality. |
|  |  |
| Nokia, NSB | We see no need for this. Similar PSD issue exist also on 5/6 GHz bands, and specific enhancements have not been deemed as necessary there either. |
| OPPO | The PUCCH power control formula modification is needed, but taking the regulatory power limit into account is more reasonable. |
| vivo | We share the same view with Nokia. |
| Intel | We do not see any need for this change, but further discussion and clarification may be needed. |
| InterDigital | We don’t see the need to update. |
| Apple | We do not see a need for this. |
| Futurewei | We see much effort is required if the power control functionality is to be updated taking into account of the regularitory power limits into account. |
| CATT | The change is actuall quite simple and straightforward. Without the change, the mechanism of PUCCH power control will be changed. |
| NTT DOCOMO | We share the same view with Nokia NSB, i.e. no seed for this as it seems the same issue as in 5/6 GHz bands. |
| LG Electronics | We share the same view with Nokia and don’t see the need for modification. |
| Samsung | We agree with Nokia’s comment. |
| ZTE, Sanechips | We don’t see the need to modify the formula. |
| Lenovo, Motorola Mobility | Share the same view as Nokia. No need for modification of PUCCH power control formula. |
| Transsion | We think further discussion and clarification may be needed for power control issue due to PSD limitation. |
| Moderator | Many companies do not see a need for a change to the power control formula wit the rationale that similar PSD issues exist also in the 5/6 GHz bands, and specifica enhancements were not deemed necessary there. Several companies feel the issue should be further discussed.  FL Recommendation: De-prioritize this topic for this meeting |
|  |  |
|  |  |
|  |  |

# 7 RRC / SIB1 Parameter Issues

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| LGE [15] | **Proposal #1: It needs to clarify whether the number of RBs for enhanced PUCCH format 0, 1, and 4 can be configured differently per PUCCH resource. If RAN1 can confirm that the previous RAN1 agreement implies the number of RBs for enhanced PUCCH format 0, 1, and 4 can be configured differently per PUCCH resource, the note in the comments for row 11/12/13 in RRC parameters table for extending NR to 52.6-71GHz should be modified as follows:**   |  | | --- | | Agreement:  The maximum configured number of RBs, N\_RB, for enhanced PF 0/1/4 is given by 16 RBs for 480 and 960 kHz SCS (same as for 120 kHz SCS).  Note: RAN2 may need to determine eventually where this RRC parameter is added.  Note: It is possible to put this in PUCCH resource~~, but RAN1 agreement is the # of RB is configured per format~~ | |
| Ericsson [8] | Prior to RRC configuration, a set of cell-specific PUCCH resources are configured via SIB1 for the initial UL BWP (of the PCell). The parameter *pucch-ResourceCommon* indicates the configuration by pointing to a row index 0..15 of Table 9.2.1-1 in 38.213. The hierarchy of this parameter in 38.331 is as follows:  *SIB1 🡺 ServingCellConfigCommonSIB 🡺 UplinkConfigCommonSIB 🡺 BWP-UplinkCommon 🡺 PUCCH-ConfigCommon 🡺 pucch-ResourceCommon*  The parameter *pucch-ResourceCommon* is present only for the initial UL BWP (BWP#0) configuration provided by SIB1, i.e., for the PCell; it is absent for other BWPs. Only PUCCH formats 0 and 1 can be configured prior to RRC, and we see no reason to change this for the 52.6 – 71 GHz band.  pucch-ResourceCommon INTEGER (0..15) OPTIONAL, -- Cond InitialBWP-Only   |  |  | | --- | --- | | **Conditional Presence** | **Explanation** | | *InitialBWP-Only* | The field is mandatory present in the [*PUCCH-ConfigCommon*](#TPUCCHConfigCommon) of the initial [BWP](#TBWP) (BWP#0) in SIB1. It is absent in other BWPs. |   Additionally, we observe that according to RAN1 and RAN level agreements, initial access (i.e., on PCell) is supported only for 120 and 480 kHz SCS. Hence 960 kHz SCS is not needed for the initial UL BWP. Hence we propose:  **Proposal 1 For PUCCH resource sets prior to RRC configuration, support only 120 and 480 kHz SCS.** |
| Nokia [9] | ***Proposal 1:*** *For the SIB1 parameter that configures the number of RBs for a cell-specific PUCCH resource set, the value range contains all integer values in the range [1 .. N\_RB\_Max], where N\_RB\_Max is the maximum number of RBs.* |

### **Summary of RRC / SIB1 Parameter Issues**

Several companies have provided issues related to RRC and SIB1 parameters:

1. In [15] it is proposed to clarify that the number of RBs can be configured differently for each PUCCH resource
2. In [8] it is proposed to capture that PUCCH resource sets prior to RRC configuration are supported for 120 and 480 kHz only
3. In [9] it is proposed to clarify the value range for the SIB1 parameter that configures the number of RBs for the PUCCH resources prior to RRC

For the 2nd and 3rd issues, the moderator proposes that these are discussed in the following email thread on RRC parameters:

[106bis-e-R17-RRC-60GHz] Email discussion on Rel-17 RRC parameters for supporting NR from 52.6 GHz to 71 GHz – Jing (Qualcomm)

* 1st check point: October 14
* Final check point: October 19

For the 1st issue, it seems like some discussion is needed in this email thread first, and then subsequent discussion can occur in the RRC parameter email thread.

In Rel-15 (and Rel-16 without interlacing), the number of RBs for PF2/3 is configured per PUCCH resource. There is an RRC parameter within the PUCCH resource definition for each of PUCCH formats 2 and 3 separately where the number of RBs is configured (see below extract from the IE *PUCCH-Config* from 38.331). For example, the gNB could configure one PF2 resource with X1 RBs, a 2nd PF2 resource with X2 RBs, and a 3rd PF3 resource with X3 RBs.

PUCCH-Resource ::= SEQUENCE {

pucch-ResourceId PUCCH-ResourceId,

startingPRB PRB-Id,

intraSlotFrequencyHopping ENUMERATED { enabled } OPTIONAL, -- Need R

secondHopPRB PRB-Id OPTIONAL, -- Need R

format CHOICE {

format0 PUCCH-format0,

format1 PUCCH-format1,

format2 PUCCH-format2,

format3 PUCCH-format3,

format4 PUCCH-format4

}

}

PUCCH-format0 ::= SEQUENCE {

initialCyclicShift INTEGER(0..11),

nrofSymbols INTEGER (1..2),

startingSymbolIndex INTEGER(0..13)

}

PUCCH-format1 ::= SEQUENCE {

initialCyclicShift INTEGER(0..11),

nrofSymbols INTEGER (4..14),

startingSymbolIndex INTEGER(0..10),

timeDomainOCC INTEGER(0..6)

}

PUCCH-format2 ::= SEQUENCE {

nrofPRBs INTEGER (1..16),

nrofSymbols INTEGER (1..2),

startingSymbolIndex INTEGER(0..13)

}

PUCCH-format3 ::= SEQUENCE {

nrofPRBs INTEGER (1..16),

nrofSymbols INTEGER (4..14),

startingSymbolIndex INTEGER(0..10)

}

PUCCH-format4 ::= SEQUENCE {

nrofSymbols INTEGER (4..14),

occ-Length ENUMERATED {n2,n4},

occ-Index ENUMERATED {n0,n1,n2,n3},

startingSymbolIndex INTEGER(0..10)

}

In RAN1#106-e we made the following agreement

Agreement:

* Support an RRC parameter to configure the number of RBs for a PUCCH resource for each of enhanced PUCCH formats 0, 1, and 4
* The parameter is provided by dedicated signaling (per UE) per BWP

While it may not be 100% clear from this agreement, it was the moderator's intention when drafting the proposal in the last meeting that the same principle should be followed for Rel-17. To clarify, the moderator proposes the following.

### **Proposal #2 (Number of RBs per PUCCH resource)**

* Update the following RAN1#106-e agreement to clarfiy that the number of RBs can be configured separately per PUCCH resource

Update of RAN1#106-e Agreement:

* Support an RRC parameter to configure the number of RBs ~~for a~~ per PUCCH resource for each of enhanced PUCCH formats 0, 1, and 4
* The parameter is provided by dedicated signaling (per UE) per BWP
* Update the description of the RRC parameter accordingly within the RRC parameter email thread

Please provide your company view on Proposal #2

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | The moderator's recommendation is to support Proposal #2 as this was the moderator's intention when drafting the original proposal. This is consistent with the way the number of RBs is configured for PF2/3 in Rel-15 and Rel-16 (without interlacing). |
| Huawei/HiSilicon | We are fine with Proposal 2. |
| Nokia, NSB | We support Proposal #2. |
| OPPO | We are OK with Proposal #2. |
| vivo | We are fine with Proposal 2. |
| Intel | We are fine with Proposal #2. |
| InterDigital | We are fine with Proposal #2. |
| Qualcomm | We are fine the proposal 2 |
| Apple | We are fine with Proposal #2 |
| Futurewei | We are ok with Proposal #2. |
| CATT | OK with the proposal. |
| NTT DOCOMO | We support Proposal #2. |
| LG Electronics | We support Proposal #2 and agree with Moderator’s view. |
| Samsung | We are OK with Proposal #2. |
| ZTE, Sanechips | We are fine with Proposal #2 |
| Lenovo, Motorola Mobility | We support Proposal #2 |
| Sony | We are okay with Proposal #2. |
| Transsion | We support Proposal #2. |
| Moderator | There is consensus to support Proposal #2, hence the moderator will recommended it for email endorsement. |

# 8 UE Capability Issues

The following table provides a summary of company proposals on this topic:

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| OPPO [6] | **Proposal 3: Reporting UE capability or maximum supported number of RBs in RRC\_CONNECTED should be supported.** |

### **Summary of UE Capability Issues**

One company proposes that a UE capability reporting is supported for the maximum number of RBs for a PUCCH resource for RRC connected mode.

The moderator proposes that this discussion is handled in the following email thread on UE capability issues.

[106bis-e-R17-UE-features-60GHz-01] Email discussion UE features for supporting NR from 52.6 GHz to 71 GHz – Ralf (AT&T)

* 1st check point: October 14
* Final check point: October 19

# References

1. R1-2108624, "FL Summary #3 for [106-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4," Moderator (Ericsson), RAN1#106-e, August 2021.
2. R1-2108769 Enhancement on PUCCH formats Huawei, HiSilicon
3. R1-2108784 On Enhancement of PUCCH Resource Set for 52.6GHz to 71GHz FUTUREWEI
4. R1-2108936 Discussion on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
5. R1-2108961 Discussions on PUCCH enhancements for NR operation from 52.6GHz to 71GHz vivo
6. R1-2109072 Discussion on enhancements for PUCCH format 0/1/4 OPPO
7. R1-2109210 Enhancements for PUCCH formats for up to 71GHz operation CATT
8. R1-2109435 PUCCH enhancements Ericsson
9. R1-2109444 Remaining items for enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
10. R1-2109478 Enhancements for PUCCH format 0/1/4 for NR from 52.6 GHz to 71 GHz Samsung
11. R1-2109600 Discussion on PUCCH enhancements for extending NR up to 71 GHz Intel Corporation
12. R1-2109667 PUCCH format 0/1/4 enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
13. R1-2109779 Additional considerations on enhancements for PUCCH formats 0/1/4 Sony
14. R1-2109905 Discussions on enhancements for PUCCH formats 0/1/4 InterDigital, Inc.
15. R1-2109963 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics
16. R1-2110023 Discussion on Enhancements for PUCCH formats 0/1/4 Apple
17. R1-2110174 Enhancements for PUCCH for NR in 52.6 to 71GHz band Qualcomm Incorporated