3GPP TSG-RAN WG1 Meeting #107-e R1-2111466

e-Meeting, 11th – 19th November, 2021

Agenda Item: 8.2.3

Source: Moderator (Ericsson)

Title: FL Summary for [107-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:

[107-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4 with checkpoints for agreements on November 15 and 19 – Steve (Ericsson)

# 2 Handling of PUCCH Resource Set Index 15 Prior to Dedicated PUCCH Configuration

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Sony [9] | **Proposal 1: For PUCCH resource set index 15, select** $X=N\_{RB}$**.** |
| ZTE [5] | **Proposal 1: For PUCCH resource set index 15, Alt-a:** $X=N\_{RB}$**X=N\_RB should be adopted.** |
| Futurewei [3] | ***Proposal 1. If a fractional value X is considered for scaling the PRB offset of PUCCH resource set 15, it is better to absorb X into the floor(***$∙$***) operation, i.e.,*** $\left⌊N\_{BWP}^{size}∙X/4\right⌋$***.*** ***Proposal 2. If a value X independent of*** $N\_{RB}$ ***is considered for scaling the PRB offset of PUCCH resource set 15, it is recommended that X=1 is adopted.***  |
| Intel [12] | **Proposal 1: For resource set index 15,** $X=N\_{RB}$**.****Proposal 2: It is left to gNB implementation to avoid any error case related to a potential RB shortage issue.** |
| Ericsson [10] | Proposal 1 In the RAN1#106bis-e agreement on construction of PUCCH resource sets prior to dedicated PUCCH configuration, support scaling value X = 1 for PUCCH resource set index 15 (Alt-b in the agreement). |
| CATT [7] | Proposal 3 For PUCCH resource set index 15 which has reserved enough PRB offset for inter-cell frequency division multiplexing, it is prefer to support$ X=1$. |
| Nokia [6] | ***Proposal 1:*** *Alt-a (*$X=N\_{RB})$ *is applied also with PUCCH resource set index 15.* |
| Apple [14] | ***Proposal 1:*** *For the construction of PUCCH resource sets prior to dedicated PUCCH configuration, X = 1 for PUCCH resource set index 15.* * *It will be up to gNB implementation to configure the values of* $N\_{BWP}^{size}$ *and* $N\_{RB}$ *to ensure that there are enough PUCCH resources.*
 |
| Qualcomm [17] | **Proposal 1: For index 15 in table 9.2.1, we support Alt-a to use same procedure as other indexes to construct common PUCCH resource.** |
| LGE [15] | **Proposal #1: Adopt the following CR where X=**$N\_{RB}$ **for PUCCH resource set index 0 to 14 and X=1 for the PUCCH resource set index 15:**

|  |
| --- |
| If $\left⌊{r\_{PUCCH}}/{8}\right⌋=0$ 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 $RB\_{BWP}^{offset}∙X+\left(\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $N\_{BWP}^{size}-RB\_{BWP}^{offset}∙X-\left(1+\left⌊{r\_{PUCCH}}/{N\_{CS}}\right⌋\right)∙N\_{RB}$, where $N\_{CS}$ is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes, and $X=1$ if *pucch-ResourceCommon* indicates index 15 and $X=N\_{RB}$ otherwise-     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $r\_{PUCCH}modN\_{CS}$If $\left⌊{r\_{PUCCH}}/{8}\right⌋=1$ 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 $N\_{BWP}^{size}-RB\_{BWP}^{offset}∙X-\left(1+\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $RB\_{BWP}^{offset}∙X+\left(\left⌊{\left(r\_{PUCCH}-8\right)}/{N\_{CS}}\right⌋\right)∙N\_{RB}$, where $X=1$ if *pucch-ResourceCommon* indicates index 15 and $X=N\_{RB}$ otherwise-     the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $\left(r\_{PUCCH}-8\right)modN\_{CS}$ |

 |
| Huawei [2] | ***Proposal 1: For PUCCH resource set index 15, the PUCCH resources are determined in the same way as that of PUCCH resource set indices 0…14. (Alt-a:*** $X=N\_{RB}$***)*** |
| NTT DOCOMO [16] | **Proposal 1: For PUCCH before dedicated PUCCH configuration, PRB offset definition for PUCCH resource set index 15 should be the same as index 0-14 for multiple PRB allocation (Alt-a in the agreement at RAN1#106bis-e meeting).** |
| vivo [4] | **Proposal 1: For the FFS, down select to one of the alternatives for PUCCH resource set index 15, we support alt-a:** $X=N\_{RB}$**.** |

## Summary of Handling of PUCCH Resource Set Index 15

Based on company contributions, two alternatives are identified for handling of PUCCH resource set index 15 used prior to dedicated PUCCH configuration, where X is the scaling value agreed in the CR in RAN1#106bis-e

* Alt-1: X = NRB
	+ Sony, ZTE, Intel, Nokia, Qualcomm, Huawei, NTT DOCOMO, vivo
* Alt-2: X = 1
	+ CATT, Futurewei(?), Ericsson, Apple, LGE

Companies supportive of Alt-1 generally say that any error cases that occur can be handled by gNB implementation, and that a consistent scaling principle is desired for all PUCCH resource set indices.

Some companies supportive of Alt-2 observe that according to the Rel-15 design intention, PUCCH resources in set 15 are designed to hop within the center NBWP/2 RBs of the BWP, i.e., the RB offset creates an "RB offset area" of NBWP/4 RBs at the low and high ends of the BWP that are not used (see Figure 1 from [15] below). Furthermore in Rel-15, the second hop for the first 8 resources in the set is designed to have a larger RB index than the first hop and vice versa for the last 8 resources in the set. These companies oberve that if X = NRB, the frequency hopping steps into the RB offset area and the hopping pattern reverses, i.e., the second hop is at a lower frequency than the first hop for the first 8 resources (see Figures 2 and 3 from [15] below).



RB offset area

Figure 1. An example of PUCCH resource configuration for the case of NRB=1



Figure 2. An example of PUCCH resource configuration for the case of NRB=2



Figure 3. An example of PUCCH resource configuration for the case of NRB=3

Hence the trade-off between Alt-1 and Alt-2 seems to be the following:

* Alt-1: Same scaling value X = NRB for all PUCCH resource sets 0 .. 15, but for set 15
	+ Different hopping pattern compared to sets 0..14
	+ RB offset area (NBWP/4 RBs) on each end of BWP is occupied, contrary to Rel-15
* Alt-2: Different scaling value X = 1 used for set 15 compared to sets 0 .. 14, but for set 15
	+ Same hopping pattern as for sets 0 .. 14
	+ RB offset area (NBWP/4 RBs) on each end of BWP is not occupied, as per Rel-15

## **Question #1: What is your view on the above trade-offs between Alt-1 and Alt-2?**

Please provide your view on Question #1 above in addition to your preference for Alt-1 or Alt-2. Please also indicate if your position is flexible.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | We need to down-select to one of Alt-1 and Alt-2 in this meeting. However, before doing so, it seems relevant to discuss the trade-offs between the two approaches identified above.The moderator points out that the issue is not whether or not PUCCH resources step outside the BWP; that error case is already handled by the below conclusion from RAN1#106bis-e for both Alt-1 and Alt-2. The issue is rather about the hopping pattern and whether or not the "RB offset" area is occupied. Conclusion:* 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
 |
| Nokia, NSB | We have a sligh preference for Alt-1 as we want to maintain a consistent scaling principle for all PUCCH resource set indices. |
| Huawei, HiSilicon | Our preference is Alt-1, for simplicity. Considering the large carrier frequencies and bandwdiths the WI focuses on, we do not expect any noticeable performance difference of either alternative.  |
|  |  |

# 3 Sequence Design for Multi-RB PUCCH

## 3.1 Sequence Design for DMRS of Multi-RB PF1

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| vivo [4] | **Proposal 2: The DMRS for enhanced PF1 supports a single sequence of length equal to the total number of mapped REs of the PUCCH-DMRS resource is used.** |

### Summary of Sequence Design for DMRS of Multi-RB PF1

vivo [4] observes that it is not clear whether the below RAN1#106-e agreement for multi-RB PF0/1 also applies to the DMRS of PF1.

Agreement (RAN1#106-e):

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 checked the current draft CR for 38.211 [18] prepared by the 38.211 editor, and indeed, Section 6.4.1.3.1.1 on DMRS for PF1 has not been updated to include the case of NRB > 1.

Hence the moderator makes the following proposal to ensure that the next version of the 38.211 draft CR will capture this.

### **Proposal #1 (Sequence design for DMRS of multi-RB PF1)**

For DMRS of enhanced PF1 support a single sequence of length equal to the total number of mapped REs of of the PUCCH resource is used. The spreading factor for DMRS of enhanced PF1 is defined in the same way as Rel-16.

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

Please provide your company view on Proposal #1.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator | Support Proposal #1 |
| Nokia, NSB | We support the Proposal #1 |
| Huawei, HiSilicon | We support Proposal #1. |
|  |  |

## 3.2 Sequence Design for DMRS of Multi-RB PF4

There are no company contributions on this topic; however, when the moderator checked the draft CR for 38.211 [18] for the issue discussed in Section 3.1 above, the moderator discovered that Section 6.4.1.3.3.1 of 38.211 on DMRS for PF4 contains the following:

The reference-signal sequence $r\_{l}\left(m\right)$ shall be generated according to



where $M\_{sc}^{PUCCH,s}$ is given by clause 6.3.2.6.3 and $r\_{u,v}^{\left(α,δ\right)}(m)$ depends on the configuration:

- if the higher-layer parameter *dmrs-UplinkTransformPrecodingPUCCH* is configured, and ${π}/{2}$-BPSK is used for PUCCH, $r\_{u,v}^{\left(α,δ\right)}(m)$ is given by clause 5.2.3 with $δ=0$ and $c\_{init}$ given by clause 6.4.1.3.2.1. The sequence group $u$ and the sequence number $v$ depend on the sequence hopping in clause 6.3.2.2.1.

- otherwise, $r\_{u,v}^{\left(α,δ\right)}(m)$ is given by clause 6.3.2.2 and the cyclic shift $α$ varies with the symbol number and slot number according to clause 6.3.2.2.2 with

- $m\_{0}=0$ for PUCCH format 3 without interlaced mapping;

- $m\_{0}$ obtained from Table 6.4.1.3.3.1-1 with the orthogonal sequence index $n$ given by clause 6.3.2.6.3 for PUCCH format 3 with interlaced mapping and PUCCH format 4.

This text says that if ${π}/{2}$-BPSK is used for PF4, then the DMRS sequence is defined in Section 5.2.3 which defines Type-2 low PAPR sequences which are based on ${π}/{2}$-BPSK symbols. This is in contrast to Type-1 low PAPR sequences which are based on Zadoff-Chu sequences. The moderator observes that use of Type-2 low PAPR sequences conflicts with the below RAN1 agreement from RAN1#104bis-e:

Agreement (RAN1#104bis-e):

For DMRS of enhanced PF4, a Type-1 low PAPR sequence of length equal to the total number of mapped REs of of the PUCCH resource is used. Cyclic shifts are defined in the same was as Rel-15/16 for PF4 (Alt-1 in agreement from RAN1#104-e).

Based on this observation, the moderator poses the following question regarding whether or not pi/2-BPSK should be supported for enhanced PF4, i.e., if NRB > 1. Depending on company views, we can either make a new agreement or conclusion capturing the RAN1 consensus so that the next version of the 38.211 draft CR can capture the consensus.

### **Question #2 What is your view on whether or not** ${π}/{2}$**-BPSK should be supported for enhanced PF4, i.e., when** NRB > 1**?**

Please provide your company view on Question #2.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Nokia, NSB | We are ok to support ${π}/{2}$-BPSK for PF4 with Type-2 low PAPR sequences.  |
| Huawei, HiSilicon | We are uncertain about the usefulness of ${π}/{2}$-BPSK in this case. It may be applicable where coverage is an issue, but this modulation format has not been part of the RAN1 evaluations.  |
|  |  |
|  |  |

# 4 Potential Coverage Imbalance between PF2/3 and PF4

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 2: Considering the limited time for Rel-17 B52.6GHz, the discussion on potential problem of coverage performance should be deferred.**  |
| OPPO [8] | **Proposal 2: For PF2/3 in 60GHz band, 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.** |
| Nokia [6] | ***Observation 1:*** *On potential coverage imbalance between enhanced PUCCH formats 2/3 and PUCCH format 4, it has not been shown that PF2/3 cause a coverage limitation.* |
| Qualcomm [17] | **Proposal 3: In Rel-17, no further discussion on potential coverage imbalance between PF2/3 and PF4.** |
| Interdigital [13] | ***Observation 3:*** *Potential coverage imbalance issue can be handled by gNB configuration with the flexibility given by the current specification.****Proposal 1:*** *Keep the current design for PUCCH formats in NR 52-71.*  |

## Summary of Potential Coverage Imbalance

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| 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. |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting to not further discuss, the moderator proposes to de-priortize this topic for Rel-17 given the limited time left in the WI.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic for Rel-17. |
| Nokia, NSB | We support the FL recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
|  |  |

# 5 Potential Assistance Info Provided to gNB

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 3: There is no need for UE to report beamforming gain to gNB.** |
| Futurewei [3] | ***Proposal 3. Discuss further the necessity of an explicit assistance information for gNB to determine*** $N\_{RB}$ ***such as beamforming gain.***  |
| Intel [12] | **Proposal 3: A UE operating in shared spectrum is expected to report its TX beamforming gain via either Msg3 PUSCH or PRACH resource partitioning.** |
| CATT [7] | **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.** |
| Nokia [6] | ***Observation 2:*** *UE assistance information for PUCCH resource configuration is an optimisation that should be deprioritized at this phase of WI.*  |
| Qualcomm [17] | **Proposal 2: In Rel-17, Assistance Info on number of RBs for multi-RB PF 0/1 is not supported.** |
| Interdigital [13] | ***Proposal 2:*** *No potential assistance information and power control enhancement are supported in Rel-17.* |

## Summary of Potential Assistance Information Provided to gNB

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| 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 |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting that provision of assistance info should not be supported, the moderator proposes to de-priortize this topic for Rel-17 given the limited time left in the WI.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic for Rel-17. |
| Nokia, NSB | We support the FL Recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
|  |  |

# 6 PUCCH Power Control

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| ZTE [5] | **Proposal 4: It is proposed not to discuss the power control of PUCCH until RAN4 determines some parameters such as PSD limitation and the maximum conduct power.** |
| CATT [7] | **Proposal 4 It is needed to modify the maximum transmission power in the PUCCH power control formula for different configured number of RBs.** |

### Summary of PUCCH Power Control

The summary from the discussion in RAN1#106bis-e was as follows [1]:

|  |  |
| --- | --- |
| 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 |

Given the state of the discussion in the last meeting, and the new company contributions on the topic for this meeting suggesting that any change to power control may depend on RAN4 decisions that will occur in later RAN4 meetings, the moderator proposes to de-priortize this topic, at least for now.

Of course companies are always free to provide their view, and if you which to do so, please provide it here.

|  |  |
| --- | --- |
| **Company** | **View/Position** |
| Moderator Recommendation | De-prioritize this topic |
| Nokia, NSB | We support the FL Recommendation |
| Huawei, HiSilicon | We support to de-prioritize this topic for Rel-17. |
|  |  |

# 7 RRC / SIB1 Parameter Issues

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

|  |  |
| --- | --- |
| **Company** | **Company Proposals** |
| Nokia [6] | ***Proposal 2:*** *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

One company proposes to clarify that the value range for the SIB1 parameter that configures the number of RBs for PUCCH resources prior to dedicated PUCCH configuration. According to the moderator's understanding, the value range 1 .. 16 is already captured in the RRC parameter spreadsheet provided to RAN2 [19], hence there shouldn't be a need to further discuss.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NR\_ext\_to\_71GHz | PUCCH | nrofPRBs | New | Number of PRB for for PUCCH resource sets before dedicated PUCCH resource configuration | {1,…,16} | PUCCH-ConfigCommon |

# References

1. R1-2110499, "FL Summary #2 for [106bis-e-NR-52-71GHz-03] Email discussion/approval on enhancements for PUCCH formats 0/1/4," Moderator (Ericsson), RAN1#106bis-e, October 2021.
2. R1-2110829 Enhancement on PUCCH formats Huawei, HiSilicon
3. R1-2110874 Discussion on Enhancements of PUCCH formats for Beyond 52.6GHz FUTUREWEI
4. R1-2111000 Remaining issues on PUCCH enhancements for NR operation from 52.6GHz to 71GHz vivo
5. R1-2111076 Discussion on the PUCCH enhancements for 52.6 to 71GHz ZTE, Sanechips
6. R1-2111197 Remaining items for enhanced PUCCH formats 0/1/4 Nokia, Nokia Shanghai Bell
7. R1-2111243 Enhancements for PUCCH formats for up to 71GHz operation CATT
8. R1-2111309 Discussion on enhancements for PUCCH format 0/1/4 OPPO
9. R1-2111387 Views on enhancements for PUCCH formats 0/1/4 Sony
10. R1-2111465 PUCCH enhancements Ericsson
11. R1-2111466 FL Summary for Enhancements for PUCCH formats 0/1/4 Ericsson
12. R1-2111485 Discussion on PUCCH enhancements for extending NR up to 71 GHz Intel Corporation
13. R1-2111834 Discussions on enhancements for PUCCH formats 0/1/4 InterDigital, Inc.
14. R1-2111863 Discussion on Enhancements for PUCCH formats 0\_1\_4 Apple
15. R1-2112047 Enhancements for PUCCH formats 0/1/4 to support NR above 52.6 GHz LG Electronics
16. R1-2112098 PUCCH format 0/1/4 enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
17. R1-2112205 Enhancements for PUCCH for NR in 52.6 to 71GHz band Qualcomm Incorporated
18. R1-2112431, "draft CR Introduction of extensions to 71 GHz," Ericsson, RAN1#107-e, November 2021.
19. R1-2110573, "Consolidated higher layer parameter list for Rel-17 NR," Moderator(Ericsson), RAN1#106bis-e, October 2021.