**3GPP TSG RAN WG1 #110bis-e** **R1-221xxxx**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 7.1

**Source:** Moderator (Samsung)

**Title:** Summary of [110bis-e-NR-R15-01] Discussion on PUCCH collision handling for more than two overlapped PUCCHs with repetition

**Document for:** Discussion and Decision

# Introduction

This contribution provides the summary for the following email discussion in RAN1#110bis-e:

[110bis-e-NR-R15-01] Discussion on PUCCH collision handling for more than two overlapped PUCCHs with repetition by Oct 17 – Sa (Samsung)

Section 3 provides the background information. Section 4 captures the detailed email discussions. Section 5 summarizes the outcome of the email discussion.

# Contact Points

Respondents to the email discussion are kindly asked to fill in the following table.

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| Company | Name | Email |
| Moderator (Samsung) | Sa Zhang | sa.zhang@samsung.com |
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# Background

In RAN1#109-e, more than two overlapping PUCCHs with repetitions was discussed [1] and the following conclusions were made [2].

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| Conclusion:  For resolving overlapping PUCCHs with and/or without repetitions in a slot in Rel-16, a UE first performs clause 9.2.6 (TS 38.213) to resolve overlapping PUCCHs where at least one PUCCH is with repetitions, and then UE performs clause 9.2.5 (TS 38.213) to resolve overlapping PUCCHs without repetitions.   * Note: The above is performed per slot.   Conclusion:  For resolving overlapping PUCCHs with repetitions in clause 9.2.6 of TS 38.213 in Rel-16, PUCCHs with repetitions and PUCCHs overlapping with a PUCCH with repetitions are considered. PUCCHs without repetitions that do not overlap with a PUCCH with repetitions are not considered.   * Note 1: The above is for clarifying the determination of the overlapping PUCCHs resolved in clause 9.2.6 of TS 38.213 and does not impact the determination of “a set of overlapping PUCCHs” when performing clause 9.2.6 of TS 38.213 discussed in [109-e-NR-CRs-03]. * Note 2: The above has no spec impact. This is also assumed in discussion to solve issue in [109-e-NR-CRs-03].   Conclusion:  For resolving the overlapping PUCCHs with repetitions in Rel-16, the procedure of 9.2.6 of TR38.213 only performs prioritization, multiplexing is not performed in 9.2.6 of TR38.213.   * Note: the above has no spec impact.   Conclusion  For resolving overlapping PUCCHs of a same priority in Rel-16, a UE performs the following steps   * Step1, the UE resolves overlapping PUCCHs with repetitions as described in TS 38.213 clause 9.2.6, if any.   + Step 1-1: the UE determines the PUCCHs involved in TS 38.213 clause 9.2.6.     - o    PUCCHs with repetitions and PUCCHs overlapping with a PUCCH with repetitions are involved.     - o    PUCCHs without repetitions that do not overlap with a PUCCH with repetitions are not involved.   + Step 1-2: the UE resolves overlapping PUCCHs determined in Step 1-1 by performing TS 38.213 clause 9.2.6.     - o    Only prioritization is performed. * Step2, the UE resolves overlapping PUCCHs without repetitions as described in TS 38.213 clause 9.2.5, if any.   + Step 2-1: the UE determines the PUCCHs involved in TS 38.213 clause 9.2.5.     - PUCCHs without repetitions that do not overlap with a PUCCH with repetitions are involved.     - Resulting PUCCHs without repetitions of resolving overlapping PUCCHs determined in Step 1-2 are involved.   + Step 2-2: the UE resolves overlapping PUCCHs determined in Step 2-1 by performing TS 38.213 clause 9.2.5.   Note: The above conclusion on the generic framework with high-level steps has no spec impact. The details of certain steps, e.g. step 1-2, may have spec impact subject to outcome of the ongoing and future discussion on the issues identified in email thread [109-e-NR-CRs-03]. |

In RAN1#110, the issue was further discussed and the following working assumption was made [4].

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| Working Assumption  For resolving overlapping PUCCHs with repetitions of a same priority in Rel-16, a UE performs the following steps   * Step 1-2-1: the UE determines a set of overlapping PUCCHs. * Step 1-2-2: the UE performs prioritization among PUCCHs in the set of overlapping PUCCHs.   + The priority order for different UCI types is defined as: HARQ-ACK > SR > CSI with higher priority > CSI with lower priority   + For overlapping PUCCHs of the same UCI priority, the priority order for a same UCI type is defined as：PUCCH starting at an earlier slot > PUCCH starting at a later slot * Step 1-2-3: the UE repeats step 1-2-1 and step 1-2-2 until the overlapping PUCCHs with repetitions is resolved. |

8 companies discuss the remaining issues of the overlapping PUCCHs with repetitions in the submitted contributions [5] ~ [13] and the proposals are summarized below.

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| Company | Proposal |
| HW | ***Proposal 1: For a group of more than two overlapping PUCCHs at Step 1-2-1, “a set of overlapping PUCCHs” is determined by the following two steps:***   * ***Step i, a reference PUCCH is selected from all PUCCHs with repetition that overlap with at least one PUCCH in the current slot with the order of earliest symbol followed by longest duration.*** * ***Step ii, the “a set of overlapping PUCCHs” is determined as the reference PUCCH and all PUCCHs (with/without repetitions) that are overlapping with this reference PUCCH.***   ***Proposal 2: For a group of more than two overlapping PUCCHs in Step 1-2-2, the PUCCH with the highest priority/earliest slot of “a set of overlapping PUCCHs” is transmitted, while the PUCCH with any lower priority/later slot of “a set of overlapping PUCCHs” is dropped.***   * ***If there are at least two PUCCHs with the same highest priority in the “a set of overlapping PUCCHs”, the PUCCH starting at the earliest slot among the at least two PUCCHs is transmitted, while other PUCCHs are dropped.*** * ***UE does not expect any two PUCCHs of the “a set of overlapping PUCCHs” have the same UCI type as well as start at the same slot***  9.2.6 PUCCH repetition procedure < Unchanged parts are omitted >  A UE does not multiplex different UCI types in a PUCCH transmission with repetitions over slots. If a UE would transmit a first PUCCH over more than one slot and at least a second PUCCH over one or more slots, and the transmissions of the first PUCCH and the second PUCCH would overlap in a number of slots then, for each slot of the number of slots and with UCI type priority of HARQ-ACK > SR > CSI with higher priority > CSI with lower priority  - the UE does not expect any two PUCCHs from the first PUCCH and the second PUCCHs to start at a same slot and include a UCI type with same priority  - if the first PUCCH and each of the second PUCCHs include a UCI type with same priority, the UE transmits the PUCCH starting at an earliest slot and does not transmit the PUCCH starting at any later slot  - if the first PUCCH and any of the second PUCCHs do not include a UCI type with same priority, the UE transmits the PUCCH that includes the UCI type with highest priority followed by starting at an earliest slot and does not transmit the PUCCH that include the UCI type with any lower priority or any later slot  - the UE performs the above rules by selecting the first PUCCH with the order of earliest symbol followed by longest duration from the PUCCHs with repetition that overlap with at least one PUCCH, and the at least a second PUCCH includes all PUCCHs overlapping with the first PUCCH  < Unchanged parts are omitted > |
| SPRD | 1. ***The reference PUCCH is a PUCCH with repetitions to determine a set of overlapping PUCCHs.*** 2. ***The collision of all PUCCHs within the set of overlapping PUCCHs are resolved at a time, PUCCH resource with higher /highest priority or earlier/earliest slot is transmitted and the others are dropped in Step 1-2-2.*** |
| OPPO | ***Proposal 1: In step 1-2-1 for determining a set of overlapping PUCCHs, the reference PUCCH should be a PUCCH with repetitions.***  ***Proposal 2: In step 1-2-1, “a set of overlapping PUCCHs” can contain at least two PUCCHs including “a first PUCCH” with repetitions and “at least a second PUCCH” overlapping with the “first PUCCH”.***  ***Proposal 3: In step 1-2-2, within “a set of overlapping PUCCHs”, UE transmits the PUCCH with UCI type with the highest priority or earliest starting slot (when same priority) and drops all other PUCCHs.***  ***Proposal 4: In step 1-2-3, the UE repeats step 1-2-1 and step 1-2-2 until there is no PUCCH overlapping with a PUCCH with repetitions.***  ***Observation 1: There exists ambiguity on the selection order of the “reference PUCCH/first PUCCH” when there are more than one PUCCH with repetitions in a slot.***  ***Proposal 5: When there are more than one PUCCH with repetitions in a slot, RAN1 to discuss the following alternatives:***  ***Alt 1:***  ***Step a: UE selects a PUCCH with rep as the “reference PUCCH/first PUCCH” that overlap with at least one PUCCH according to the order of earliest starting symbol followed by longest duration.***  ***Step b: “A set of overlapping PUCCHs” include the “reference PUCCH/first PUCCH” and all the PUCCHs overlapping with the “reference PUCCH/first PUCCH”. UE transmits the PUCCH with UCI type with the highest priority or earliest starting slot (when same priority) and drops all other PUCCHs.***  ***Step c: repeat step a and step b until there is no PUCCH overlapping with a PUCCH with repetitions.***  ***Alt 2:***  ***Step a: UE selects a PUCCH with rep as the “reference PUCCH/first PUCCH” that overlap with at least one PUCCH according to the order of UCI priority followed by earliest starting slot then by longest duration.***  ***Step b: “A set of overlapping PUCCHs” include the “reference PUCCH/first PUCCH” and all the PUCCHs overlapping with the “reference PUCCH/first PUCCH”. UE transmits the PUCCH with UCI type with the highest priority or earliest starting slot (when same priority) and drops all other PUCCHs.***  ***Step c: repeat step a and step b until there is no PUCCH overlapping with a PUCCH with repetitions.***  ***Alt 3:***  ***UE does not expect to be configured or scheduled more than one PUCCH with repetitions in a slot.*** |
| CATT | **Observation 1: UE behavior is not clear for Option 1, 2 and 6 for the case shown in Figure 1.**  **Observation 2: For the case shown in Figure 2, only Option 4 keeps both PUCCH 1 and PUCCH 3 and other options (i.e. Option 1/2/3/5/6) additionally drop PUCCH 3.**  **Observation 3: For the case shown in Figure 3, Option 4/5/6 keep both PUCCH 1 and PUCCH 3 and other options (i.e. Option 1/2/3) additionally drop PUCCH 1.**  **Observation 4: For the case shown in Figure 4, Option 4/5 keep both PUCCH 1 and PUCCH 3 and other options (i.e. Option 1/2/3/6) additionally drop PUCCH 1.**  **Proposal: For collision handling of more than two overlapping PUCCHs with repetition, consider following Option 4 and Option 5.**   * **Option 4:** * **Step 1-2-1: Determine a first PUCCH with repetition based on UCI priority followed by starting slot/sub-slot as defined in TS 38.213 clause 9.2.6 and “a set of overlapping PUCCHs” including the first PUCCH and all the PUCCHs overlapping with the first PUCCH;** * **Step 1-2-2: Perform pair-wise prioritization between the first PUCCH and a second PUCCH until there is no overlapping between the first PUCCH and another PUCCH, where the second PUCCH is selected based on UCI priority followed by starting slot/sub-slot as defined in TS 38.213 clause 9.2.6 within “a set of overlapping PUCCHs”.** * **Option 5:** * **Step 1-2-1: Determine a first PUCCH based on UCI priority followed by starting slot/sub-slot as defined in TS 38.213 clause 9.2.6 and “a set of overlapping PUCCHs” including the first PUCCH and all the PUCCHs overlapping with the first PUCCH** * **Step 1-2-2: Keep the first PUCCH and drop all the other PUCCHs within “a set of overlapping PUCCHs”.** |
| Intel | **Proposal 1: For resolving overlapping PUCCHs of a same priority in Rel-16, a UE performs the following steps**   * **Step 1-2-1: the UE determines a set of overlapping PUCCHs according to existing pseudo-code in clause 9.2.5** * **Step 1-2-2: the UE performs prioritization among PUCCHs in the set of overlapping PUCCHs with only one survived PUCCH**   + **The priority order for different UCI types is defined as: HARQ-ACK > SR > CSI with higher priority > CSI with lower priority**   + **For overlapping PUCCHs of the same UCI priority, the priority order for a same UCI type is defined as：PUCCH starting at an earlier slot > PUCCH starting at a later slot** * **Step 1-2-3: the UE repeats step 1-2-1 and step 1-2-2 until the overlapping PUCCHs with repetitions is resolved.** |
| ZTE | ***Proposal 1:*** *To perform prioritization among PUCCHs in the set of overlapping PUCCHs, UE would transmit the highest priority channel(s) in the set of overlapping PUCCHs. If there are two or more non-overlapping PUCCHs with UCI of highest priority, all of them will be transmitted.*  ***Proposal 2****: For the determination of reference PUCCH in the set of overlapping PUCCHs with repetitions, the reference PUCCH can be a PUCCH with or without repetitions.* |
| Samsung | **Proposal: For resolving more than two overlapping PUCCHs of the same priority, reuse the pseudo-code in TS 38.213 9.2.5 with the restriction of selecting up to 2 PUCCH resources and apply the rules defined in clause 9.2.6 if there is repetition or clause 9.2.5, otherwise. Adopt the following TP for section 9.2.5 and 9.2.6 of TS38.213.**  -------------------------------------------------- Start of text proposal ---------------------------------------------------  **9.2.5 UE procedure for reporting multiple UCI types**  <Unchanged text omitted>  Set  to the cardinality of  Set to be the first symbol of resource  in the slot  Set  to be the number of symbols of resource  in the slot  Set  - index of first resource in set  Set  - counter of overlapped resources  while  if  and resource  overlaps with resource  and the resources in set do not include a PUCCH with repetitions, or  and resource overlaps with resource , , and the resources in set include at least one PUCCH with repetitions      else  if  determine a single resource for multiplexing UCI associated with resources  as described in clauses 9.2.5.0, 9.2.5.1, ~~and~~ 9.2.5.2 and 9.2.6  set the index of the single resource to    % start from the beginning after reordering unmerged resources at next step    % function that re-orders resources in current set  Set  to the cardinality of  else    end if  end if  end while  <Unchanged text omitted>  **9.2.6 PUCCH repetition procedure**  <Unchanged text omitted>  A UE does not multiplex different UCI types in a PUCCH transmission with repetitions over slots. If a UE would transmit a first PUCCH over more than one slot and ~~at least~~ a second PUCCH over one or more slots, and the transmissions of the first PUCCH and the second PUCCH would overlap in a number of slots then, for each slot of the number of slots and with UCI type priority of HARQ-ACK > SR > CSI with higher priority > CSI with lower priority  - the UE does not expect the first PUCCH and ~~any of~~ the second PUCCH~~s~~ to start at a same slot and include a UCI type with same priority  - if the first PUCCH and ~~any of~~ the second PUCCH~~s~~ include a UCI type with same priority, the UE transmits the PUCCH starting at an earlier slot and does not transmit the PUCCH starting at a later slot  - if the first PUCCH and ~~any of~~ the second PUCCH~~s~~ do not include a UCI type with same priority, the UE transmits the PUCCH that includes the UCI type with higher priority and does not transmit the PUCCH that include the UCI type with lower priority  If a UE would transmit more than two overlapping PUCCH transmissions in a slot, where at least one PUCCH transmission is with repetitions over slots, the UE resolves the overlapping for PUCCH transmissions in the slot using the pseudo-code in clause 9.2.5.  <Unchanged text omitted>  ----------------------------------------------------- End of text proposal ------------------------------------------------ |
| QC | ***Proposal 1: Adopt the following TP for Rel-*** 9.2.6 PUCCH repetition procedure \*\*\*\* unchanged text omitted \*\*\*\*\*\*  A UE does not multiplex different UCI types in a PUCCH transmission with repetitions over slots. If a UE would transmit a first PUCCH over more than one slot and at least a second PUCCH over one or more slots, and the transmissions of the first PUCCH and the second PUCCH would overlap in a number of slots then, for each slot of the number of slots and with UCI type priority of HARQ-ACK > SR > CSI with higher priority > CSI with lower priority  - the UE does not expect the first PUCCH and any of the second PUCCHs to start at a same slot and include a UCI type with same priority  - if the first PUCCH and any of the second PUCCHs include a UCI type with same priority, the UE transmits the PUCCH starting at an earlier slot and does not transmit the PUCCH starting at a later slot  - if the first PUCCH and any of the second PUCCHs do not include a UCI type with same priority, the UE transmits the PUCCH that includes the UCI type with higher priority and does not transmit the PUCCH that include the UCI type with lower priority  If a UE would transmit a group of overlapping PUCCH channels {Q(j-o+1),…,Q(j)} with a same priority index as described in Clause 9.2.5 in a slot, and if at least one of the PUCCH in the group is repeated over more than one slots, the UE transmits the PUCCH with the highest priority in the group in the slot using the procedures described above and does not transmit the other PUCCH(s) in the group. |

# Email Discussion

In RAN1#110e 7 candidate options were proposed by companies and companies’ preferences are quite diverse. It seems not possible to directly converge to a candidate option. In this meeting, moderator’s suggestion is separately discussing each of the remaining issues and try to better align companies’ view. Considering this is the late CR phase, the solution should aim for minimizing specification impact.

## First round

## Determination of a set of overlapping PUCCHs

All the submitted contributions [5] ~ [13] discussed the details of Step 1-2-1 of the following WA. The common understanding is that the set of overlapping PUCCHs consist of a reference PUCCH and PUCCH(s) overlapping with the reference PUCCH. A UE first determines a reference PUCCH and then determines the PUCCHs overlapping with the reference PUCCH.

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| Working Assumption  For resolving overlapping PUCCHs with repetitions of a same priority in Rel-16, a UE performs the following steps   * Step 1-2-1: the UE determines a set of overlapping PUCCHs. * Step 1-2-2: the UE performs prioritization among PUCCHs in the set of overlapping PUCCHs.   + The priority order for different UCI types is defined as: HARQ-ACK > SR > CSI with higher priority > CSI with lower priority   + For overlapping PUCCHs of the same UCI priority, the priority order for a same UCI type is defined as：PUCCH starting at an earlier slot > PUCCH starting at a later slot * Step 1-2-3: the UE repeats step 1-2-1 and step 1-2-2 until the overlapping PUCCHs with repetitions is resolved. |

One controversial issue is whether the reference PUCCH should be a PUCCH with repetitions. The input is summarized below.

Alt 1: The reference PUCCH is a PUCCH with repetitions.

Proponents: HW, SPRD, OPPO, CATT

Alt 2: The reference PUCCH is a PUCCH with or without repetitions.

Proponents: CATT, Intel, QC, Samsung, ZTE

The proponents of Alt 1 think ‘the first PUCCH’ in clause 9.2.6 is the reference PUCCH, to align with clause 9.2.6 the reference PUCCH should be with repetitions. The proponents of Alt 2 would like to reuse the pseudo-code in clause 9.2.5 to minimize specification impact. However, the concern of Alt 2 is that the set of overlapping PUCCHs may not include a PUCCH with repetitions and UE may resolve overlapping PUCCHs without repetitions first. Alt 2 contradicts with the conclusion copied below.

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| Conclusion:  For resolving overlapping PUCCHs with and/or without repetitions in a slot in Rel-16, a UE first performs clause 9.2.6 (TS 38.213) to resolve overlapping PUCCHs where at least one PUCCH is with repetitions, and then UE performs clause 9.2.5 (TS 38.213) to resolve overlapping PUCCHs without repetitions.   * Note: The above is performed per slot. |

This issue was discussed in RAN1#110, Alt 1 was also supported by vivo and MTK. Moderator suggest to go with the majority view.

Another issue is whether up to one or all the PUCCHsoverlapping with the reference PUCCH should be included in the set of overlapping PUCCHs**.** The inputs are summarized below.

Option 1: All the overlapping PUCCH

Proponents: HW, SPRD, OPPO, QC, Intel

Option 2: Up to one overlapping PUCCH

Proponents: Samsung

Considering there is a clear majority view, moderator would suggest to go with Option 1.

#### **P1:**

**For resolving overlapping PUCCHs with repetitions of a same priority in Rel-16, a set of overlapping PUCCHs consist of a reference PUCCH and all the PUCCHs overlapping with the reference PUCCH.**

* **A UE first determines a reference PUCCH and then determines all the PUCCHs overlapping with the reference PUCCH.**
* **The reference PUCCH is a PUCCH overlaps with at least another PUCCH.**
* **FFS: The reference PUCCH is a PUCCH with repetitions.**

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#### **Q1**

**Can you live with the restriction that the reference PUCCH is a PUCCH with repetitions? If not, please address the concern that Alt 2 may contradict previous conclusion.**

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Another remaining issue is the order of reference PUCCH determination. The inputs are summarized below.

Alt 1: Earliest starting symbol followed by longest duration

Proponents: HW OPPO, QC, Samsung, Intel

Alt 2: UCI with the highest priority

Proponents: OPPO, CATT

Alt 3: UE does not expect to be configured or scheduled more than one PUCCH with repetitions in a slot.

Proponents: OPPO

The proponents of Alt 1 aim to minimize specification impact by reusing the rules defined in clause 9.2.5. Alt 2 has additional specification impact compared with Alt 1. Alt 3 is very restrictive for the scenario of multiple traffic types. For such scenario, a SR configuration can be associated with a logic channel and multiple SR configurations can be configured in a same slot. Alt 3 prevents such scheduling flexibility. Moderator suggest to go with the majority view.

#### **P2:**

**For resolving overlapping PUCCHs with repetitions of a same priority in Rel-16, the PUCCH resources are ordered as following for determining the reference PUCCH.**

**- a resource with earlier first symbol is placed before a resource with later first symbol**

**- for two resources with same first symbol, the resource with longer duration is placed before the resource with shorter duration**

**- for two resources with same first symbol and same duration, the placement is arbitrary**

**Note: the above does not imply that the reference PUCCH is with or without repetitions.**

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## Prioritization among PUCCHs in the set of overlapping PUCCHs

There are two alternatives for determining the PUCCHs overlapping with the reference PUCCH. The inputs are summarized below.

Alt 1: UE transmit the PUCCH with the highest priority.

Proponents: HW, SPRD, OPPO, QC, Intel, CATT, Samsung

Alt 2: Perform pair-wise prioritization between the first PUCCH (reference) and a second PUCCH until there is no overlapping between the first PUCCH and another PUCCH, where the second PUCCH is selected based on UCI priority followed by starting slot/sub-slot.

Proponents: CATT

#### **P3:**

**For resolving overlapping PUCCHs with repetitions of a same priority in Rel-16, UE transmits the PUCCH with the highest priority when performing prioritization among PUCCHs in a set of overlapping PUCCHs.**

* **The priority order for different UCI types is defined as: HARQ-ACK > SR > CSI with higher priority > CSI with lower priority**
* **For overlapping PUCCHs of the same UCI priority, the priority order for a same UCI type is defined as: PUCCH starting at an earlier slot > PUCCH starting at a later slot**

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In addition, ZTE raised a case that there are more than one non-overlapping PUCCHs with the highest priority in a set of overlapping PUCCH, in this case, all the non-overlapping PUCCHs with the highest priority should be transmitted. Companies are encouraged to provide the view on this case.

#### **Q2:**

What is your option on the case that there are more than one non-overlapping PUCCHs with the highest priority in a set of overlapping PUCCH?

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## Second round

# Summary and conclusions

# Reference

1. [R1-2205342](file:///F:\\3GPP\\RAN1\\TSGR1_109-e\\Docs\\R1-2205342.zip), Summary of [109-e-NR-CRs-03] Collision of more than two overlapped PUCCHs with repetition, Moderator (Samsung), RAN1#109-e, May, 2022.
2. RAN1 Chairman’s Notes, 3GPP TSG RAN WG1 Meeting #109-e, May, 2022.
3. R1-2207913, Summary of Collision handling for overlapping PUCCHs with repetitions, Moderator (Samsung), RAN1#110, Aug., 2022.
4. RAN1 Chairman’s Notes, 3GPP TSG RAN WG1 Meeting #110, Aug., 2022.
5. [R1-2208446](file:///F:\3GPP\RAN1\TSGR1_110b-e\Docs\R1-2208446.zip), Discussion on the collision of overlapped PUCCHs with repetition, Huawei, HiSilicon
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12. [R1-2209688](file:///F:\3GPP\RAN1\TSGR1_110b-e\Docs\R1-2209688.zip), Discussion on more than two overlapping PUCCHs with repetitions, Samsung
13. [R1-2209932](file:///F:\3GPP\RAN1\TSGR1_110b-e\Docs\R1-2209932.zip), Issue on PUCCH overlapping with PUCCH with repeatitions, Qualcomm Incorporated