3GPP TSG-RAN WG2 Meeting #124 R2-231xxxx

Chicago, USA, November 13th – 17th, 2023

Source: CATT

Title: Report of [POST124][034][adv. receiver] 38.331 (CATT)

Agenda Item: 7.25.1.7

Document for: Discussion and Decision

# Introduction

This is the report of the following email discussion:

* [POST124][034][adv. receiver] 38.331 (CATT)

 Intended outcome: Update 38.331 with RAN4 new agreements, agree to 38.331 extract key questions for RAN4 and LS to RAN4 for key questions.

 Deadline: 2 weeks

# Background information

## RAN2 task

An LS on MIMO advanced receivers [1] is received by RAN2 at this meeting as follows:

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| Within the Release 18 work item on further enhancement on NR demodulation performance evolution (NR\_Demod\_enh3), RAN4 has discussed the need for UE network assistance signalling for MU-MIMO advanced receiver(s) for the UEs capable of utilizing advanced receiver supporting cancellation of 1 or more co-scheduled UEs.As an outcome, RAN4 has agreed it is beneficial to introduce new Rel-18 RRC based network assistance signalling to assist UEs supporting MU-MIMO advanced receiver(s) by providing additional information related to co-scheduled UE(s).Regarding the content of the Rel-18 new RRC network assistance signalling, RAN4 has agreed the need for the following:Dedicated RRC signalling is provided to the UE (target UE) to indicate the information in each of the following bullets separately, when the information is available:* For the target and any co-scheduled UEs in different CDM groups and with the same DMRS sequence, whether the target UE can assume the precoding and resource allocation of the co-scheduled UE are the same in the PRG-level grid configured to the target UE when PRG=2 or 4.
* Whether the DM-RS power boosting configurations (i.e., Number of DM-RS CDM groups without data, TS38.214 table 4.1-1) of all the co-scheduled UE(s), which has the same DM-RS sequence as the target UE, is the same as the target UE.
* Whether the time domain resource assignment for PDSCH symbols of all the co-scheduled UE(s), which has the same DM-RS sequence as the target UE, is same as the target UE.
* The MCS table with the highest modulation order among all MCS tables configured to the co-scheduled UE(s), which has the same DM-RS sequence as the target UE. The MCS table is one of the following:
	+ 1024QAM MCS table(s) (Table 5.1.3.1-4 from TS38.214)
	+ 256QAM MCS table(s) (Table 5.1.3.1-2 from TS38.214)
	+ 64QAM MCS tables (Table 5.1.3.1-1 or 5.1.3.1-3 from TS38.214)

Note: The terminology “the same DMRS sequence” in the above represents the same root DMRS sequence r(n) in TS38.211 Section 7.4.1.1.1.In addition, RAN4 agrees that the existence of the MU-MIMO DCI signalling, as included in the LS R4-2309895, is configured by RRC signalling. |

Regarding above LS, RAN4 agreed to introduce RRC based network assistance signaling to assist UEs supporting MU-MIMO advanced receiver(s). And RAN2 is supposed to capture these components in RRC spec.

**Observation 1: RAN2 is supposed to capture the network assistance signaling for advanced receiver in TS 38.331.**

## RAN1 progress

After receiving LS [2] as below:

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| Within the Release 18 work item on NR demodulation performance evolution (NR\_demod\_enh3), RAN4 has studied the required signalling overhead for the advanced receiver to cancel inter-user interference for MU-MIMO. 2 candidate advanced receivers, E-MMSE-IRC and R-ML, are included in the study.Based on RAN4’s evaluation, RAN4 observes that R-ML receiver can achieve better performance in most scenarios. To enable the implementation of R-ML receiver within feasible complexity, RAN4 has agreed that it is beneficial to have DCI based network assistant signalling to know the essential information related to the interfering layers associated with the co-scheduled UE(s).

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| **Bit field mapped to index** | **Content** |
| 0 | No co-scheduled UE(s) which has same DMRS sequence as target UE exists |
| 1 | In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have QPSK scheduled |
| 2 | In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 16QAM scheduled |
| 3 | In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 64QAM scheduled |
| 4 | In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 256QAM scheduled |
| 5 | In all the PRBs allocated to the target UE, all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 1024QAM scheduled |
| 6 | Not covered by cases corresponding to index 0~5. In each individual PRB allocated to the target UE, the following condition is satisfied:Only single modulation order is allocated for the co-scheduled UE(s) which has the same DMRS sequence as the target UE, if the co-scheduled UE(s) exist |
| 7 | Others |

1. The existence of MU-MIMO DCI signalling is configured by RRC signalling.
2. The field is intended to be included in a DCI which can be based on the format 1\_1.
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RAN1#114 made the following agreements on advanced receiver accordingly:

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| AgreementImplement the DCI signaling in [R1-2306361](file:///D%3A%5C%5C%E5%B7%A5%E4%BD%9C%5C%5C3GPP%E4%BC%9A%E8%AE%AE%5C%5CRAN2%5C%5CRAN2%23124%5C%5CR18%E8%A7%A3%E8%B0%83%E5%A2%9E%E5%BC%BA%5C%5CDocs%5C%5CR1-2306361.zip) (R4-2309895) in RAN1 specifications with the following assumptions.* Scope of this DCI signaling at least applying to a PDSCH satisfying all the following conditions.
	+ The PDSCH is scheduled by DCI format 1\_1.
		- Support for this feature for other DCI format(s) can be later added depending on RAN4 input
	+ Single TRP based scheme is configured for the PDSCH transmission.
	+ Single codeword is configured for the PDSCH transmission.
	+ CBG based transmission is not configured for the PDSCH transmission.
	+ Rel-15/16/17 DMRS is configured for the PDSCH transmission.
* For “Bit field mapped to index” =0, the content “No co-scheduled UE(s) which has same DMRS sequence as target UE exists” is interpret as the following.
	+ In all the PRBs allocated to the target UE, there is no co-scheduled UE or there is co-scheduled UE but with a different DMRS sequence.
* The terminology “the same DMRS sequence” in the DCI signaling table is interpret as the same root DMRS sequence r(n) in TS38.211 Section 7.4.1.1.1.
* “Bit field mapped to index” =7 in the DCI signaling table is interpret as including all the cases not covered by cases corresponding to “Bit field mapped to index” 0/1/2/3/4/5/6.
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And after further RAN4 clarification from LS [3], the conclusion made in RAN1#115 are as follows:

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| **[R1-2312340](file:///C%3A%5C%5CUsers%5C%5Cxingyanping%5C%5CAppData%5C%5CLocal%5C%5CTemp%5C%5C360zip%24Temp%5C%5CDocs%5C%5CR1-2312340.zip)**     Moderator summary #1 of discussion of Reply LS on required DCI signalling for advanced receiver on MU-MIMO scenario        Moderator (Qualcomm)**Conclusion**On the required DCI signalling for advanced receiver on MU-MIMO scenario, there is no consensus to support this new signaling in DCI format 1\_2 for advanced receiver on MU-MIMO scenario in Rel-18.  **Conclusion**On the required DCI signalling for advanced receiver on MU-MIMO scenario, there is no consensus to support this new DCI signaling when M-TRP scheme is switched to S-TRP scheme dynamically via DCI.**Agreement**On the required DCI signalling for advanced receiver on MU-MIMO scenario, the “Co-scheduled UE information” field in a DCI is reserved if 2 codewords are scheduled with the DCI. **Conclusion**On the required DCI signalling for advanced receiver on MU-MIMO scenario, there is no consensus to support the new signaling in DCI when the RRC *codeBlockGroupTransmission* is configured |

There is no further progress in advanced receiver compared to RAN1#114, and RAN1#115 just confirmed there is no consensus to support additional scenarios. And from RAN2 perspective, the observation is the DCI assistance signalling for advanced receiver is only included in DCI format 1\_1, i.e., DCI format 1\_2 is not supported.

**Observation 2: RAN1 confirms the DCI assistance signalling for advanced receiver is only included in DCI format 1\_1.**

## RAN4 progress

In the latest RAN4#109 meeting, the WF [4] for advanced receiver is approved. After checking the details, the new agreements are maily for UE capabilities, and not related to network RRC signaling.

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| **The basic UE capability with R-ML receiver for MU-MIMO (for all UE types):*** UE is capable of MU-MIMO with R-ML for 2 layers across target and co-scheduled UEs under 2RX conditions
* UE is capable of MU-MIMO with R-ML up to 2,3, or 4 layers across target and co-scheduled UEs under 4RX conditions

**The UE Types to be covered in terms of #layers it can process with R-ML:**1. Capability when modulation order is signaled (index 1-5)
	1. Up to *maxNumberMIMO-LayersPDSCH* layers across target and co-scheduled UEs in 2 RX and 4RX condition
2. Capability when modulation order is not signalled (index 6)
	1. UE cannot support R-ML
	2. UE can support 2 layers across target and co-scheduled UEs with 2RX and 4RX
	3. UE can support 2 layers across target and co-scheduled UEs with 2RX and can support *maxNumberMIMO-LayersPDSCH* layers across target and co-scheduled UEs with 4RX
3. Capability when modulation order is not signalled (index 7)
	1. UE is not expected to support R-ML

**Other details for the R-ML capability signalling*** + Applicable to the capability signalling exchange between UEs (V2X WI only)”: N/A
	+ No FDD/TDD difference
	+ FR1 only
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**Observation 3: no further progress in network RRC signaling has been made in RAN4#109 (Nov meeting).**

# Discussion

## Question 1

To sum up current information, RAN2 is supposed to capture the network assistance signaling for advanced receiver in TS 38.331, and the necessary input is still based on RAN4 LS [1]. Furthermore RAN1 confirms advanced receiver DCI signaling is only included in DCI format 1\_1.

According to online discussion and companies’ papers, there are still some potential issues RAN2 may need to check with RAN4, e.g.,

1. What is the granularity (per BWP, per Cell, per CG or per UE ) of the assistance signalling to assist UEs supporting MU-MIMO advanced receiver? [5]
2. Whether the RRC assistance signaling is independent to the RRC signaling of informing the UE the existence of MU-MIMO DCI or there is conditional relation between them. [5]
3. Whether the following assumption no longer needs to be signalled to the UE [6]:

- The DM-RS power boosting configurations (i.e., Number of DM-RS CDM groups without data) of all co-scheduled UE(s), which have the same DM-RS sequence of the target UE, are the same as the target UE.

Considering “RAN1 agreed that CDM groups without data are not used for data transmission for co-scheduled users in the same serving cell, which seems to nullify the need to indicate whether the DM-RS power boosting configurations (number of DM-RS CDM groups without data) of co-scheduled UE(s) with the same DM-RS sequence of the target UE are the same as the target UE.”

Regarding the issues above, Rapporteur provides the following suggestions as workarounds.

1. **On granularity:**

Since the advanced receiver enhancement is for the improvement of PDSCH performance and enable MU-MIMO, RAN2 can assume the granularity of network RRC signalling is per BWP as current *pdsch-Config* field is configured per BWP.

1. **On independency:**

RAN2 assumes the RRC assistance signalling is independent to the RRC signalling of informing the UE the existence of MU-MIMO DCI. In Rapporteur’s view, RRC assistance signalling of MU-MIMO is relatively static, and Co-scheduled UE information DCI filed is for one-shot downlink scheduling, thus more flexible. They can be configured separately.

1. **On DMRS power boosting configurations:**

RAN2 implements a CR following original RAN4 LS [1], i.e., DMRS power boosting information is kept for now, then check with RAN4 whether it’s feasible. Further update can be made if RAN4 has further clarifications.

**Question 1: regarding the RRC CR and LS to RAN4, which way forward do you prefer?**

**Option 1: aiming to have a RRC CR agreed (which means to be added in R18 RRC spec).**

RRC CR is implemented with the Rapporteur’s suggestions above, and send an LS to RAN4 to check whether the implemented RRC CR is feasible.

**Option 2: aiming to have a RRC CR endorsed (which means this is still a running CR, and not to be added in R18 RRC spec for now)**

RRC CR is implemented with the Rapporteur’s suggestions above, and send an LS to RAN4 to check whether the implemented RRC CR is feasible.

**Option 3: postpone this RRC CR.**

Send an LS to RAN4 to ask for the feedback on the issues above. The RRC CR can be drafted after RAN4 further clarification is received.

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| **Company** | **Preferred option****(e.g., 1, or , 2, or, 3)** | **Comments** |
| CATT | Prefer 1 | We understand the intention is to capture the RAN4 requested RRC signaling in spec as R18 outcome of advanced receiver. Since there is still some time before ASN.1 freezing, further update can be done after further clarification is received from RAN4. |
| China Telecom | Option 1 | We agree with the rapporteur’s suggestion.Regarding the granularity, take mcs-Table as an example, the legacy “mcs-Table” configuration is per BWP, so it is reasonable to configure mcs-Table in the assistance information to follow the same granularity.Regarding the independency, based on the LS from RAN4 to RAN1 and RAN2, it is quite clear that “the existence of MU-MIMO DCI signalling is configured by RRC signaling”. In our understanding, the network assistance information and the RRC signalling of informing the UE the existence of MU-MIMO DCI are independent.Regarding the DMRS power boosting configurations, as clarified online, we think RAN4’s LS is already clear that it is needed. Our understanding is that ‘UE may assume that CDM groups without data are not used for data transmission for any co-scheduled user in the same serving cell’ does not fully give the required information from the RAN4 perspective.The information that the target UE actually need is the same ‘ratio of EPRE to DMRS EPRE’ for all UEs, which is important for the target UE to perform correct channel estimation to the co-scheduled UEs with the same DMRS sequence.Such conclusion is made in RAN4 approved WF R4-2305914 in RAN4#106bis:

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| **Issue 1-2-2-5: DMRS power boosting for the co-scheduled UE***Way forward*–    DMRS power boosting should be the same for both target and the co-scheduled UE.–    … |

And according to TS38.214 table 4.1-1, the same ‘ratio of EPRE to DMRS EPRE’ between UEs, is ensured by the same ‘Number of DM-RS CDM groups without data’ configurations between target and co-scheduled UEs.From the RAN1 spec there is no limitation that the target UE is configured ‘Number of DM-RS CDM groups without data’ = 2 and co-UE is configured ‘Number of DM-RS CDM groups without data’ = 1. Following the RAN1 conclusion as sited, the target UE need not to perform demodulation on all the PRBs included in its DMRS CDM groups. But such configuration will still cause wrong channel estimation to the co-UE and fail the R-ML process for all other PRBs for this NR scheduling.So we think the RRC indication is still needed as included in the RAN4 LS.Based on the above, we think the RRC signaling design work can be conducted based on RAN4 requirements and RAN2 assumptions. To be more efficient, we prefer to agree the CR and send an LS to RAN4 to check whether the implemented RRC CR is feasible. |
| Nokia | Option 2 or Option 3 | We think it is ok for RAN2 to try to endorse a CR now, but it does not make a lot of sense to agree to a CR if there are still details that we want to double check with RAN4, e.g. related to the DMRS power boosting assumption. It is better to wait to capture things properly than to rush a CR agreement, which might result in us changing/dummifying parameters one or two meetings later. We are also ok to clarify details with RAN4 first before attempting to endorse/agree on any CR. |
| Apple | Option 1 | We share the same view as CATT and China Telecom. Regarding to remaining details to double check with RAN4, we don’t think they are essential enough to make the CR unagreeable, and thereby they can be fixed in ASN.1 review if any issue.  |
| Qualcomm | Option 2 | If there are some different understandings and needs to check with RAN4 especially for the DMRS power boosting things. We would suggest to only to have a CR to be endorsed and further clarify with RAN4. |
| ZTE | Option 1 | Similar View as Apple/CATT/China Telecom, according to the on-line discussion, companeis are encouraged to confirm RAN4 internally, and if there is no essential issue, we can agree the CR by involving the consencus that are achieved in RAN4. |
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## Question 2

Regarding the following RRC signaling in RAN4 LS [1]:

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| In addition, RAN4 agrees that the existence of the MU-MIMO DCI signalling, as included in the LS R4-2309895, is configured by RRC signalling. |

As in [6], it is proposed as below:

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| MU-MIMO DCI configuration:Regarding the need to inform the UE of the existence of the MU-MIMO DCI, this can be handled the same way as other DCIs, i.e. by informing the UE of the DCI under the *SearchSpace* configuration. Since the content/design of the MU-MIMO DCI is still under discussion by RAN1, it remains to be seen whether any further aspects related to the DCI configuration will be need to signalled by RRC.**Proposal 6**: **UE supporting advanced receiver is informed of the existence of MU-MIMO DCI via *SearchSpace* configuration. FFS whether any additional details of the MU-MIMO DCI configuration need to be indicated to the UE based on RAN1’s agreements.** |

And in [8], the proposals are as below:

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| **Proposal 2: Introduce one indication to indicate the presence of MU-MIMO DCI signaling in DCI format 1\_1.****Proposal 3: The indications above are added in IE *PDSCH-Config*, and the CR R2-2313338 is taken as baseline.** |

The difference between [6] and [8] is whether to capture this indication (for the presence of MU-MIMO DCI signaling in DCI format 1\_1) in *SearchSpace* configuration (in IE *PDCCH-Config*) or together with other components for advanced receiver in IE *PDSCH-Config*.

In Rapporteur’s view, the MU-MIMO DCI signaling is used to indicate the exact co-scheduled UE information for one-shot downlink scheduling, e.g., “all the co-scheduled UE(s), which has the same DMRS sequence as the target UE, have 16QAM scheduled”. And it’s similar to the static RRC assistance information, i.e., “The MCS table with the highest modulation order among all MCS tables configured to the co-scheduled UE(s), which has the same DM-RS sequence as the target UE.” Since these two bullets are both for modulation order information, but just with different granularities, it seems good to provide them together in IE *PDSCH-Config*.

**Question 2: regarding the indication for “the existence of the MU-MIMO DCI signalling”, which option do you prefer?**

**Option 1:** As in [6], it’s via *SearchSpace* configuration (in IE *PDCCH-Config*).

**Option 2:** As in [8], it’s configured together with other components for advanced receiver in IE *PDSCH-Config*.

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| **Company** | **Preferred option****(e.g., 1, or , 2)** | **Comments** |
| CATT | Prefer 2 | It seems easier to track all advanced receiver related assistance information within the same IE. |
| China Telecom | Slightly prefer option 2. | No strong view. Agree with CATT that Option2 is easier to track all advanced receiver related assistance information within the same IE. Option1 is also fine to us, if it is the majority’s view. |
| Nokia | Option 1 or something other than Option 2 | We think Option 2 contradicts the suggested workaround mentioned above:**On independency:**RAN2 assumes the RRC assistance signalling is independent to the RRC signalling of informing the UE the existence of MU-MIMO DCI. In Rapporteur’s view, RRC assistance signalling of MU-MIMO is relatively static, and Co-scheduled UE information DCI filed is for one-shot downlink scheduling, thus more flexible. They can be configured separately.We agree with the rapporteur’s analysis regarding independency and would prefer the signalling design to support that principle. Although we suggested in our contribution [6] that the MU-MIMO DCI configuration could be provided via *SearchSpace* configuration, we can also support it being signalled to the target UE in *PDSCH-Config*. However, we think it is not good to strictly tie the MU-MIMO DCI configuration to the signalled assumptions for advanced receiver. |
| Apple | Option 2 | We basically agree with Rapporteur’s analysis. But our view is strong, option 1 is also fine if it is majority view. |
| Qualcomm | either | No strong view. But we share the same view with Rapporteur that ‘RRC assistance signalling is independent to the RRC signalling of informing the UE the existence of MU-MIMO DCI.’ |
| ZTE | Option 2 | We slightly prefer option 2, considering the cross carrier scheduling case, if we include it search space, maybe more specification work is needed. |
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## Question 3

**Question 3: regarding the RRC CR implementation and LS to RAN4, please provide any other comments (if any) in the following table.**

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| **Company** | **Comments** |
| Nokia | Our understanding is that the MU-MIMO DCI configuration already provides some details to the target UE about the co-scheduled UEs. Therefore, if the UE knows about the existence of MU-MIMO DCI configuration it could be sufficient for the UE to activate, i.e. “set up”, advanced receiver configuration. In that sense, there might not be any requirement to adopt a SetupRelease structure to signal the network-signalled assumptions to the target UE, and a SEQUENCE structure could be sufficient to tell the UE to apply the non-default assumptions. In any case, as we mentioned in Question 2, we think it is probably better to separate the MU-MIMO DCI configuration from the network assistant signalling assumptions.We also prefer to check explicitly with RAN4 regarding the need to keep the DMRS power boosting assumption based on the latest agreement in RAN1. |
| Qualcomm | Regarding the RRC CR, our main concern is that we should keep UE’s legacy behavior, i.e., assume those RRC parameter setting of all the co-scheduled UE(s) is NOT the same as the target UE when those fields are not configured. Because UE can not know whether network supports this advanced receiver feature w/o explicit indication.For DMRS power boosting assumption, we are fine to check the RAN4/RAN1 based on the latest RAN1 agreements. |
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## CR review

If in Q1, option 1 or option 2 is adopted, and if in Q2, option 2 is adopted, a draft CR is provided for further review. Please add bubble comments in the draft RRC CR.

The draft CR is based on [7] with the following major updates:

1. Setuprelease structure is used instead of Sequence structure;
2. ENUMERATED {false} is used for *precodingAndResourceAllocation*, *dmrsPowerBoosting*, *pdsch-TimeDomainAllocation*. And the field descriptions of the fields above are also updated according to lte-NeighCellsCRS-Assumptions-r17 field (which also uses ENUMERATED {false}).

# Conclusion

Based on the discussions above, it is proposed:

# Reference

1. R2-2311739, LS on network assistant signalling for advanced receivers, Nokia.

[2] R4-2309895, LS on required DCI signalling for advanced receiver on MU-MIMO scenario, Qualcomm.

[3] R4-2317011, Reply LS on required DCI signalling for advanced receiver on MU-MIMO scenario, HiSilicon, Apple, China Telecom

[4] R4-2321114, WF for advanced receiver for MU-MIMO, China Telecom, Apple

[5] R2-2313483, Discussion on the network assistant signalling for advanced receivers, Huawei, HiSilicon

[6] R2-2313204, Discussion on signalling to support MU-MIMO advanced receivers, Nokia, Nokia Shanghai Bell

[7] R2-2313338, Introduction of network RRC signalling for advanced receiver, CATT

[8] R2-2312064, Discussion on network signalling for advanced receivers, CATT