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

**e-Meeting, May 10th – 27th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: FL summary #2 on other aspects of UE complexity reduction for RedCap**

**Agenda item: 8.6.1.4**

**Document for:** **Discussion and Decision**

# Introduction

This document presents a summary of submitted contributions to AI 8.6.1.4 (Other aspects of RedCap complexity reduction), including considerations on maximum number of DL MIMO layers and relaxed maximum modulation order for RedCap devices.

[105-e-NR-R17-RedCap-04] Email discussion regarding other aspects of UE complexity reduction – Debdeep (Intel)

* 1st check point: 5/21
* 2nd check point: 5/25
* Final check: 5/27

Based on the submitted contributions to RAN1 #105-E meeting, the discussion points are categorized into the following topics:

* Max number of DL MIMO layers for RedCap
* MCS and CQI tables for RedCap
* Miscellaneous

**Please provide your feedback to the FL Proposals 6, 7, 8, and Question 1 by May 24th, 23:59 UTC.**

# Max number of DL MIMO layers for RedCap

The WID on Rel-17 RedCap lists the following objectives [1]:

* *Maximum number of DL MIMO layers:*
	+ *For a RedCap UE with 1 Rx branch, 1 DL MIMO layer is supported.*
	+ *For a RedCap UE with 2 Rx branches, 2 DL MIMO layers are supported.*

For the indication of a max number of DL MIMO layers, the existing per-band indication of ***maxNumberMIMO-LayersPDSCH*** can be reused for RedCap UEs. This view is expressed in the following contributions: [2], [5], [7], [8], [12], and [16].

It has been noted that some adjustments to the definition of the UE capability via ***maxNumberMIMO-LayersPDSCH***, including the range of values, may be necessary considering support of 1 Rx branch and thus, a minimum value of one for ***maxNumberMIMO-LayersPDSCH***. However, such details can be left up to RAN2 once the parameter and associated value range are provided from RAN1 as part of UE features for Rel-17 RedCap.

Also, it can be seen from the above that there is a one-to-one mapping between number of Rx branches and max number of DL MIMO layers. Further, as pointed out in [2], the appropriate interpretation of the objective on reduced number of Rx branches is that the support of a number of Rx branches is band-specific. While this may be best confirmed as part of discussions for AI 8.6.1.2, the following FL Proposal aims to decide on the indication of max number of DL MIMO layers for a RedCap UE.

## FL Proposal 1

* *For a RedCap UE, existing per-band indication of UE capability on maximum number of DL MIMO layers via* ***maxNumberMIMO-LayersPDSCH*** *is reused to indicate support of max of one or two DL MIMO layers.*
	+ *Details, including any necessary adaptation compared to that for non-RedCap UEs, up to RAN2.*

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| **Company** | **Agree (Y/N)** | **Comments** |
| NordicSemi | N | This is already discussed in 8.6.1.2 by Hong. We provided input there. |
| ZTE, Sanechips | Y |  |
| Nokia, NSB |  | Same comment as NordicSemi |
| LG | Y | We think this topic can be discussed in 8.6.1.2 as it is on the capability reporting of the number of Rx braches of RedCap UEs, rather than the aspect of max MIMO layers. |
| Ericsson | Y | Same comment as others above. |
| **FL** |  | **Based on above feedback, the discussion on capability signaling for max # of DL MIMO layers will continue in AI 8.1.6.2.** |
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Following from the reduction in max number of DL MIMO layers and other simplifications, some companies (e.g., [4], [5], and [14]) propose to consider optimizations of non-fallback scheduling DCI formats (1\_1/0\_1 and 1\_2/0\_2) to reduce DCI format size. However, multiple other companies (e.g., [7], [8], [15], [16], [17]) also indicate that such optimizations of DCI formats are not warranted, and for some of the cases, such adaptation of DCI bit-fields can be possible already. For instance, [5] proposes that bit-fields in DCI formats 1\_1/1\_2 for the second PDSCH TB may be removed. However, this can already be realized by setting ***maxNrofCodeWordsScheduledByDCI*** = 1.

Further, [5] proposes that DCI formats 1\_1/0\_1 and 1\_2/0\_2 are all optional for RedCap UEs. While it may be reasonable to expect DCI formats 1\_2/0\_2 to be optional (also expected to be discussed in context of AI 8.6.1.2), making DCI format 1\_1/0\_1 (mandatory for non-RedCap UEs) run the risk of coupling dependency on UE-optional features as well as UE-optional L1 signaling mechanisms, and may unnecessarily complicate the specifications on UE capability requirements for RedCap. For instance, it is not clear on handling of certain optional features, if supported by the UE, but corresponding L1 signaling may not be supported as the UE does not support any of the non-fallback DCI formats. On the other hand, [14] indicates considering DCI format 1\_2 as a starting point for non-fallback DL DCI format for RedCap, although it is not clear if the intention is to modify DCI format 1\_1 or only mandate support of DCI format 1\_2, etc.

Considering the above, and the fact that decision on details of DCI format design may be more appropriate/timely once the basic features are in place, the following is proposed.

## FL Proposal 2

* *For a RedCap UE, following DCI formats are mandatory:*
	+ *DCI formats 1\_0/0\_0, and*
	+ *DCI formats 1\_1/0\_1*
* *For a RedCap UE, following DCI formats are optional:*
	+ *DCI formats 0\_2/1\_2*
* *FFS: any modifications to any of the above pairs of scheduling DCI formats specific to RedCap*

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| **Company** | **Agree (Y/N)** | **Comments** |
| NordicSemi | N | This is already discussed in 8.6.1.2 by Hong. We provided input there |
| ZTE, Sanechips |  | This proposal is overlapping with that in thread [105-e-NR-R17-RedCap-02]. We can discuss this issue in that email thread. |
| Nokia, NSB |  | Same comment as NordicSemi |
| LG | Y | This can be discussed in 8.6.1.2. |
| Ericsson | Y | Same comment as others above. |
| **FL** |  | **Based on above feedback, the discussion on capability signaling for max # of DL MIMO layers will continue in AI 8.1.6.2.** |
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Multiple companies (e.g., [2], [7], [8], [15], [17]) also indicate that there may not be a need to pursue simplifications to CSI processing and/or reporting framework in view of reduced max number of DL MIMO layers, and related simplifications (e.g., rank-restriction) can be already achieved with proper gNB configuration. Accordingly, the following is proposed.

## FL Proposal 3

* ***Conclusion:*** *For a RedCap UE, modifications to CSI measurement and/or reporting mechanisms are not pursued in Rel-17, at least when motivated by reduced max number of DL MIMO layers.*

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| **Company** | **Agree (Y/N)** | **Comments** |
| NordicSemi | Y |  |
| vivo | Y |  |
| ZTE, Sanechips | Y |  |
| Nokia, NSB | Y |  |
| LG | Y |  |
| Ericsson | Y |  |

**Status update (May 19, 2021):**

The following was agreed as a conclusion during GTW session on May 19, 2021.

**Conclusion**:

* For a RedCap UE, when motivated by reduced max number of DL MIMO layers modifications to CSI measurement and/or reporting mechanisms are not pursued in Rel-17.

# MCS and CQI Tables for RedCap

The WID on Rel-17 RedCap lists the following objectives [1]:

* *Relaxed maximum modulation order:*
	+ *Support of 256QAM in DL is optional (instead of mandatory) for an FR1 RedCap UE.*
	+ *No other relaxations of maximum modulation order are specified for a RedCap UE.*

Also, during RAN1 #104-E meeting, the following were agreed:

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| Agreements:* *The MCS tables currently defined are re-used for RedCap UEs*
	+ *FFS which MCS table is the default one for RedCap (i.e., the default one for non-RedCap UEs or the one with low SE entries)*
	+ *FFS mandatory/optional of the MCS tables*
	+ *Note: there is no new MCS table to be introduced for RedCap UEs*

Agreements:* *The CQI tables currently defined are re-used for RedCap UEs.*
	+ *FFS mandatory/optional of the CQI tables*
	+ *There is no new CQI table to be introduced for RedCap UEs*
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With 256QAM in DL/UL being optional for RedCap UEs, the 64QAM “default” MCS tables (Table 5.1.3.1-1 for DL and UL OFDM and Table 6.1.4.1-1 for UL w/ transform precoding respectively) and the 64QAM low spectral efficiency (SE) MCS tables (Table 5.1.3.1-3 for DL and UL OFDM and Table 6.1.4.1-2 for UL w/ transform precoding respectively) are identified as primary contenders for mandatory requirements.

Towards this, the views from different companies can be categorized as below.

* Mandatory support of 64QAM “default” MCS tables (Table 5.1.3.1-1 for DL and UL OFDM and Table 6.1.4.1-1 for UL w/ transform precoding respectively)
	+ [2], [4], [5], [7], [8], [9], [11], [12], [13], [14], [15], [17] (12 companies)
* Mandatory support of 64QAM low SE MCS tables (Table 5.1.3.1-3 for DL and UL OFDM and Table 6.1.4.1-2 for UL w/ transform precoding respectively)
	+ [3], [6] (Two companies)
	+ 64QAM SE tables are used for common control, including at least random access-related PDSCH/PUSCH scheduling.
* Mandatory support of 256QAM MCS table (Table 5.1.3.1-2 for DL/UL OFDM)
	+ [2] (One company)

Based on the above summary of views, the following is proposed.

## FL Proposal 4

* *For a RedCap UE, 64QAM “default” MCS tables (Table 5.1.3.1-1 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-1 in TS 38.214 for UL w/ transform precoding respectively) are mandatory.*
* *The following may be optionally supported by RedCap UEs:*
	+ *256QAM MCS tables (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM)*
	+ *64QAM low SE MCS tables (Table 5.1.3.1-3 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively)*

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| **Company** | **Agree (Y/N)** | **Comments** |
| NordiSemi | Y |  |
| Vivo | Y |  |
| ZTE, Sanechips | Y |  |
| Nokia, NSB | Y |  |
| LG | Y |  |
| Ericsson | Y, partially | In our understanding, in Rel-15/16, support of 256QAM MCS table is mandatory for legacy UEs, regardless of whether the UE supports 256QAM or not. We think there is benefit in aligning the support of 256QAM tables for RedCap and legacy UEs. Therefore, we propose the following update to the proposal:* *For a RedCap UE, 64QAM “default” MCS tables (Table 5.1.3.1-1 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-1 in TS 38.214 for UL w/ transform precoding respectively) are mandatory.*
	+ *FFS: Whether 256QAM MCS table (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM) should be mandatory.*
* *The following may be optionally supported by RedCap UEs:*
	+ *~~256QAM MCS tables (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM)~~*
	+ *64QAM low SE MCS tables (Table 5.1.3.1-3 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively)*
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## Based on the feedback received, FL Proposal 4 is updated as below to FL Proposal 4A.

## FL Proposal 4A

* *For a RedCap UE, 64QAM “default” MCS tables (Table 5.1.3.1-1 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-1 in TS 38.214 for UL w/ transform precoding respectively) are mandatory.*
	+ *FFS: Whether 256QAM MCS table (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM) should be mandatory.*
* *The following may be optionally supported by RedCap UEs:*
	+ *~~256QAM MCS tables (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM)~~*
	+ *64QAM low SE MCS tables (Table 5.1.3.1-3 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively)*

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| **Company** | **Agree (Y/N)** | **Comments** |
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**Status update (May 19, 2021):**

The following was agreed as a conclusion during GTW session on May 19, 2021.

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| Agreements:* For a RedCap UE, 64QAM MCS tables (Table 5.1.3.1-1 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-1 in TS 38.214 for UL w/ transform precoding respectively) are the “default” ones and are mandatory.
* The following is optionally supported by RedCap UEs:
	+ 256QAM MCS tables (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM)
	+ 64QAM low SE MCS tables (Table 5.1.3.1-3 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively)
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Similarly, the following shows the distribution of company preferences on mandatory requirements for CQI tables for RedCap UEs.

* Mandatory support of “CQI table 1” (Table 5.2.2.1-2 in TS 38.214) that corresponds to MCS Table 5.1.3.1-1 in TS 38.214 (64QAM default MCS table).
	+ [2], [4], [7], [8], [13], [14], [15] (Seven companies)
* Mandatory support of “CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)
	+ [2] (One company)

Based on the above, the following FL proposal is made. Note that the last bullet on “CQI table 3” is identified as FFS as further considerations may be necessary on whether a RedCap UE should be subject to target BLERs as low as 10^-5.

## FL Proposal 5

* *For a RedCap UE, “CQI table 1” (Table 5.2.2.1-2 in TS 38.214), that corresponds to MCS Table 5.1.3.1-1 in TS 38.214,* *is mandatory.*
* *The following may be optionally supported by a RedCap UE:*
	+ *“CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)*
	+ *FFS: “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) that corresponds to MCS Table 5.1.3.1-3 in TS 38.214 (64QAM low SE MCS table)*

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| **Company** | **Agree (Y/N)** | **Comments** |
| NordicSemi | Y | But we believe that it should be clarified that this part is not applicable to REDCAP 0.00001, if the higher layer parameter cqi-Table in CSI-ReportConfig configures 'table3' (corresponding toTable 5.2.2.1-4). |
| vivo |  | We think “CQI table 3” should be optional for redcap.  |
| ZTE, Sanechips |  | Follow the conclusion of FL Proposal 4. |
| Nokia, NSB | Y |  |
| LG |  | We also think the CQI table 3 should be optional for RedCap, if supported. |
| Ericsson | Y, partially | Similar comment as for FL Proposal 4. In Rel-15/16, support of “CQI table 2” is mandatory for legacy UEs, regardless of whether the UE supports 256QAM or not. Therefore, we propose the following update to the proposal:* *For a RedCap UE, “CQI table 1” (Table 5.2.2.1-2 in TS 38.214), that corresponds to MCS Table 5.1.3.1-1 in TS 38.214,* *is mandatory.*
	+ *FFS: Whether “CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table) should be mandatory.*
* *The following may be optionally supported by a RedCap UE:*
	+ *~~“CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)~~*
	+ *FFS: “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) that corresponds to MCS Table 5.1.3.1-3 in TS 38.214 (64QAM low SE MCS table)*
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## Based on the feedback received, FL Proposal 5 is updated as below to FL Proposal 5A.

## FL Proposal 5A

* *For a RedCap UE, “CQI table 1” (Table 5.2.2.1-2 in TS 38.214), that corresponds to MCS Table 5.1.3.1-1 in TS 38.214,* *is mandatory.*
	+ *FFS: Whether “CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table) should be mandatory.*
* *The following may be optionally supported by a RedCap UE:*
	+ *~~“CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)~~*
	+ *FFS: “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) that corresponds to MCS Table 5.1.3.1-3 in TS 38.214 (64QAM low SE MCS table)*

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| **Company** | **Agree (Y/N)** | **Comments** |
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**Status update (May 19, 2021):**

The following was agreed as a conclusion during GTW session on May 19, 2021.

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| Agreements:* For a RedCap UE, “CQI table 1” (Table 5.2.2.1-2 in TS 38.214), that corresponds to MCS Table 5.1.3.1-1 in TS 38.214, is mandatory.
* The following is optionally supported by a RedCap UE:
	+ “CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)
	+ “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) that corresponds to MCS Table 5.1.3.1-3 in TS 38.214 (64QAM low SE MCS table)
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Following the decisions from GTW session on May 19, 2021 during RAN1 #105-E, it would be necessary to decide on any conditions, including any potential coupling between the support of the optional MCS and CQI tables.

It would be natural to expect that if a UE indicates support of 256QAM in the DL, it should support 256QAM MCS and CQI tables. Further, it does not seem necessary to define any capability reporting for the support of 256QAM MCS and/or CQI tables as the capability of the MCS/CQI tables can be associated with support of 256QAM for PDSCH.

## FL Proposal 6

* *Support of 256QAM MCS table for PDSCH and support of “CQI table 2”* *(Table 5.2.2.1-3 in TS 38.214) are mandatory for a RedCap UE indicating support of 256QAM for PDSCH.*

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| **Company** | **Agree (Y/N)** | **Comments** |
| vivo |  | We would prefer the following revision * *Both ~~Support of~~ 256QAM MCS table for PDSCH and ~~support of~~ “CQI table 2”* *(Table 5.2.2.1-3 in TS 38.214) are ~~mandatory~~ supported for a RedCap UE indicating support of 256QAM for PDSCH.*
 |
| Huawei, HiSi | Y |  |
| Xiaomi |  | OK with vivo’s revision  |
| CMCC | Y |  |
| Spreadtrum | Y |  |
| Qualcomm |  | The suggested changes proposed by Vivo are preferred |
| Samsung | Y | Vivo’s version is good |
| FUTUREWEI2 | Y | Okay with vivo’s revision |
| LG | Y | Also okay with the revision suggested by vivo. |
| NordicSemi | Y |  |
| Nokia, NSB | Y | OK with vivo’s revision |

However, whether support of 64QAM low SE MCS table for DL and “CQI table 3” should be coupled needs further discussion. With a target BLER of 10^-5 for “CQI table 3”, there is non-negligible additional complexity associated with support of “CQI table 3” than just 64QAM low SE MCS table for PDSCH. It should also be noted that for non-RedCap UEs, support of 64QAM low SE MCS table for DL and “CQI table 3” are not coupled either. On the other hand, it is considerable whether to mandate support of the 64QAM low SE MCS table if “CQI table 3” is supported.

Accordingly, the following FL proposals are made.

## FL Proposal 7

* *Relationship between support of 64QAM low SE MCS table for PDSCH and support of “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) is to be down-selected from the following alternatives.*

*A RedCap UE may indicate one of:*

* + ***Alt 1:*** *(1) Support of 64QAM low SE MCS table for PDSCH only; (2) Support of “CQI table 3” only; (3) Support of 64QAM low SE MCS table for PDSCH and support of “CQI table 3”; (4) Neither*
	+ ***Alt 2:*** *(1) Support 64QAM low SE MCS table for PDSCH only; (2) Support of 64QAM low SE MCS table for PDSCH and support of “CQI table 3”; (3) Neither*
	+ ***Alt 3:*** *(1) Support of “CQI table 3” only; (3) Support of 64QAM low SE MCS table for PDSCH and support of “CQI table 3”; (3) Neither*
	+ ***Alt 4:*** *(1) Support of 64QAM low SE MCS table for PDSCH and support of “CQI table 3”; (2) Neither*
	+ *Other alternatives not precluded*

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| **Company** | **Agree (Y/N)** | **Comments** |
| vivo |  | In Rel-16 UE feature list, 64QAM low SE MCS table for PDSCH and CQI table 3 are independent features, as 5-34 and 2-32c, respectively. Following the same principle, it seems alt 1 should be supported.  |
| Huawei, HiSi | Alt1 | As only alternatives are listed we would not object. However, as the WID clearly states that: “**changes to capability signalling are specified only if necessary**”, we would prefer no changes to the report framework unless strongly deemed necessary. For this particular case, that is, they remain to be separately reported. |
| Xiaomi |  | We prefer to reuse R16 principle |
| CMCC |  | Agree with vivo and Huawei. |
| Spreadtrum |  | We share the similar views with vivo and Huawei, we also prefer to follow the same principle in Rel.16, i.e., Alt 1. |
| Qualcomm | Alt1 |  |
| Samsung | Y | We support Alt 1 |
| FUTUREWEI2 | Alt1 | We also prefer to follow the same principle in Rel.16 |
| LG | Y | Alt1 is preferred |
| NordicSemi | Alt5 | Our preference: Low SE MCS table with separate capability for support of Table 3 with BLER target 10% and Support of Table 3 with BLER target 10-5. But we are fine with Alt 1, which is the baseline assumption here  |
| Nokia, NSB | Y | We are OK with the proposal. Our preference is Alt 1. |

## FL Proposal 8

* *Support of 64QAM low SE MCS table for PDSCH (Table 5.1.3.1-3 in TS 38.214) and support of 64QAM low SE MCS tables for PUSCH (Table 5.1.3.1-3 in TS 38.214 for UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively) are not coupled and capability of each can be reported independent of the other.*

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| **Company** | **Agree (Y/N)** | **Comments** |
| vivo | Y | This is the same as Rel-16 principle.  |
| Huawei, HiSi | Y | Similar comments as in P7. |
| Xiaomi | Y |  |
| CMCC | Y |  |
| Spreadtrum | Y |  |
| Qualcomm | Y |  |
| Samsung | Y |  |
| FUTUREWEI2 | Y |  |
| LG | Y |  |
| NordicSemi | Y | No need to couple |
| Nokia, NSB | Y |  |

Another issue that was briefly touched upon during the GTW session during May 19, 2021, is whether a RedCap UE may optionally support 256QAM in the UL. In this regard, so far there has been no explicit decision to not allow a RedCap UE to optionally support 256QAM for PUSCH.

To resolve this, the following Question is raised.

## Question 1

* *In Rel-17, can a RedCap UE optionally support of 256QAM MCS table for PUSCH?*

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| **Company** | **Yes/No** | **Comments** |
| vivo | Y | Following the same principle as in some other sub-agenda items, we do not explicitly prohibit a RedCap UE to implement an optional feature unless extremely necessary.  |
| Huawei, HiSi | Y | Similar comments as in P7. |
| Xiaomi | Y |  |
| CMCC | Y |  |
| Spreadtrum  | Y |  |
| Qualcomm | N | Based on the performance requirement of UL data rates indicated in WID and the impacts on complexity/cost of RedCap UE, support for 256QAM is not necessary on UL |
| Samsung | Y | We suggest to not discuss such features one by one. Instead, we suggest agree on some general guidance on how to treat optionally supported features. For example, optionally supported features by non-RedCap UEs can be optionally supported by RedCap UE if no additional spec change is required.  |
| FUTUREWEI2 | Y |  |
| LG |  | The 256QAM in UL is not necessary for RedCap UEs. This discussion can be deferred to the feature discussion at a later stage. |
| NordicSemi | Y | if supported for RedCap, capability should be separate from DL 256Q |
| Nokia, NSB | Y | There is no need to preclude RedCap UE from optionally supporting 256-QAM in the UL. |

# Miscellaneous

In contribution [10], it is proposed that SRS transmissions outside of active UL BWP are not supported by RedCap UEs and details of frequency selective scheduling outside of active DL BWP of a RedCap UE are studied further in view of the complexities involved with accurate CSI measurements and feedback outside of the active DL BWP.

Considering that some of these considerations have some correlation to the discussions in AI 8.6.1.1 on reduced BW support for RedCap UEs, it is suggested to consider these proposals once better clarity on reduced BW and BWP configurations to be supported for RedCap UEs.

# Decisions during RAN1 #105-E

Decisions so far during RAN1 #105-E meeting:

**Conclusion**:

* For a RedCap UE, when motivated by reduced max number of DL MIMO layers modifications to CSI measurement and/or reporting mechanisms are not pursued in Rel-17.

Agreements:

* For a RedCap UE, 64QAM MCS tables (Table 5.1.3.1-1 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-1 in TS 38.214 for UL w/ transform precoding respectively) are the “default” ones and are mandatory.
* The following is optionally supported by RedCap UEs:
	+ 256QAM MCS tables (Table 5.1.3.1-2 in TS 38.214 for DL and UL OFDM)
	+ 64QAM low SE MCS tables (Table 5.1.3.1-3 in TS 38.214 for DL and UL OFDM and Table 6.1.4.1-2 in TS 38.214 for UL w/ transform precoding respectively)

Agreements:

* For a RedCap UE, “CQI table 1” (Table 5.2.2.1-2 in TS 38.214), that corresponds to MCS Table 5.1.3.1-1 in TS 38.214, is mandatory.
* The following is optionally supported by a RedCap UE:
	+ “CQI table 2” (Table 5.2.2.1-3 in TS 38.214) that corresponds to MCS Table 5.1.3.1-2 in TS 38.214 (256QAM MCS table)
	+ “CQI table 3” (Table 5.2.2.1-4 in TS 38.214) that corresponds to MCS Table 5.1.3.1-3 in TS 38.214 (64QAM low SE MCS table)

# References

1. RP-210918, Revised WID on support of reduced capability NR devices, RAN #91-e.

1. R1-2104182, MIMO and modulation support for RedCap Ericsson
2. [R1-2104190](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104190.zip), Discussion on Modulation order and parameters FUTUREWEI
3. [R1-2104286](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104286.zip), Reduced maximum MIMO layers and reduced maximum modulation order for RedCap Huawei, HiSilicon
4. [R1-2104368](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104368.zip), Other feature reductions for RedCap NR devices vivo, Guangdong Genius
5. [R1-2104430](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104430.zip), Discussion on relaxed maximum modulation order for RedCap Spreadtrum Communications
6. [R1-2104529](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104529.zip), Discussion on other aspects related to complexity reduction CATT
7. [R1-2104554](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104554.zip), Other UE Complexity Reduction Aspects Nokia, Nokia Shanghai Bell
8. [R1-2104619](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104619.zip), Discussion on other aspects of reduced UE complexity CMCC
9. [R1-2104680](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104680.zip), Other Aspects of UE Complexity Reduction Qualcomm Incorporated
10. [R1-2104713](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104713.zip), Discussion on modulation order and MIMO layers for RedCap ZTE, Sanechips
11. [R1-2104914](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104914.zip), On other complexity reduction features for RedCap Intel Corporation
12. [R1-2105114](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105114.zip), On relaxed maximum modulation order Apple
13. [R1-2105319](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105319.zip), Other aspects for complexity reduction for RedCap UEs Samsung
14. [R1-2105570](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105570.zip), Discussion on relaxed maximum modulation order and relaxed MIMO layer Xiaomi
15. [R1-2105595](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105595.zip), MIMO aspects for RedCap NEC
16. [R1-2105706](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105706.zip), Discussion on other aspects of UE complexity reduction for RedCap NTT DOCOMO, INC.

# Appendix A

**List of observations/proposals on other aspects for complexity reduction for RedCap UEs submitted to RAN1 #105-E meeting:**

[R1-2104182](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104182.zip) MIMO and modulation support for RedCap Ericsson

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| [Proposal 1 The WID is interpreted such that the maximum number of DL MIMO layers depends on the number of Rx branches supported in a particular band.](#_Toc71665468)[Proposal 2 From RAN1 perspective, existing per-band capability maxNumberMIMO-LayersPDSCH can be used for indicating both the number of Rx branches and supported number of DL MIMO layers in a band. The detailed signaling solution is up to RAN2.](#_Toc71665469)[Proposal 3 The discussion on possible changes to DCI due to reduced maximum number of DL MIMO layers is deferred to a later stage and considered jointly with all RedCap UE complexity reduction features.](#_Toc71665470)[Proposal 4 For simplicity and consistency reasons, in our view, 64QAM (Table 5.1.3.1-1 and Table 6.1.4.1-1), 256QAM (Table 5.1.3.1-2) MCS tables and CQI Table 1 and Table 2 should also be mandatory for all RedCap UEs.](#_Toc71665471)[Proposal 5 RedCap UEs can optionally support lowSE-64QAM MCS tables (Table 5.1.3.1-3 for PUSCH transmissions and PDSCH receptions with CP-OFDM and Table 6.1.4.1-2 for PUSCH transmission with transform precoding) and CQI Table 3.](#_Toc71665472)[Proposal 6 Like legacy UEs, RedCap UEs shall support the 64QAM MCS tables (Table 5.1.3.1-1 for both UL transmissions and DL receptions with CP-OFDM and 64QAM MCS Table 6.1.4.1-1 for PUSCH transmissions with transform precoding) as the default MCS tables, and allow the network to configure which MCS tables and CQI tables to use after initial access.](#_Toc71665473) |

[R1-2104190](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104190.zip) Discussion on Modulation order and parameters FUTUREWEI

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| Observation 1: The low SE table is tailored to the SNR region where a reduced Rx branch RedCap UE operates.Proposal 1: The low SE table should be the default MCS table for at least 1 Rx branch RedCap UEs.Proposal 2: The low SE MCS table for PDSCH is considered as a mandatory feature for at least 1 Rx branch RedCap UEs during feature discussions.  |

[R1-2104286](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104286.zip) Reduced maximum MIMO layers and reduced maximum modulation order for RedCap Huawei, HiSilicon

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| Proposal 1: Antenna port (s) field in DCI for RedCap can be considered to be modified for relaxed maximum number of DL MIMO layers.Proposal 2: Conclude that Table 5.1.3.1-1 and Table 6.1.4.1-1 are reused as the default MCS table, Table 5.2.2.1-2 are reused as the default CQI table for RedCap UEs.Proposal 3: Conclude that the following tables remain to be optional for RedCap UEs:* Table 5.1.3.1-3 (MCS table 3 for both PUSCH and PDSCH) defined in TS 38.214;
* Table 6.1.4.1-2 (MCS table 3 for PUSCH with transform precoding and 64QAM) defined in TS 38.214;
* Table 5.1.3.1-2 (MCS table 2 for PUSCH) defined in TS 38.214.
* Table 5.2.2.1-3 (CQI table for 256QAM );
* Table 5.2.2.1-4 (CQI table 3)
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[R1-2104368](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104368.zip) Other feature reductions for RedCap NR devices vivo, Guangdong Genius

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| Proposal 1: the number of Rx branches supported by a RedCap UE can be reported implicitly via the existing capability parameter maxNumberMIMO-LayersPDSCH.Either absence of the capability of maxNumberMIMO-LayersPDSCH or the value of oneLayer should be added to the MIMO-LayersDL of maxNumberMIMO-LayersPDSCHProposal 2: For RedCap UEs, * DCI format 0\_0/1\_0 are mandatory.
* DCI format 0\_1/1\_1 and DCI format 0\_2/1\_2 are optional.

Proposal 3: For non-fallback UL DCI format, at least following field(s) can be considered to be removed for RedCap with 1Tx.* Precoding information and number of layers, PTRS-DMRS association, CBG transmission information (CBGTI), 2nd downlink assignment index (which is used as CBG-based DAI), SRS resource indicator

Proposal 4: For non-fallback DL DCI format, at least following field(s) can be considered to be removed for RedCap with 1 or 2Rx.* Modulation and coding scheme for TB1, New data indicator for TB1, Redundancy version for TB1, CBG transmission information (CBGTI), CBG flushing out information (CBGFI)

Proposal 5: RedCap can reuse the existing capability parameters of pdsch-256QAM-FR1 or pdsch-256QAM-FR2 to indicate whether it supports 256QAM in DL FR1 or FR2.* For RedCap, the capability of pdsch-256QAM-FR1 should be optional.

Proposal 6: for RedCap UE, the default MCS table is the same as the default MCS table for non-RedCap UE and RedCap UE.  |

[R1-2104430](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104430.zip) Discussion on relaxed maximum modulation order for RedCap Spreadtrum Communications

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| Proposal 1: gNB should know the RedCap UE capability of the low-SE MCS table as early as possible, e.g. RACH procedure. Proposal 2: Capability of the low-SE MCS table is mandatory for RedCap UE.Proposal 3: Reuse the existing capability parameters pdsch-256QAM-FR1 to indicate whether the UE supports 256QAMProposal 4: Send an LS to RAN2 including RAN1 agreements on RedCap UE capability part. |

[R1-2104529](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104529.zip) Discussion on other aspects related to complexity reduction CATT

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| Observation 1: The maximum number of DL MIMO layers for RedCap UE is already clear.Proposal 1: Modification of DCI fields/formats for reduced DL MIMO layers is not considered.Proposal 2: Modification of CSI measurement/reporting mechanism for reduced DL MIMO layers is not considered.Proposal 3: The default MCS table for non-RedCap UE (i.e. Table 5.1.3.1-1 in TS 38.214) is also the default MCS table for RedCap UE.Proposal 4: The default MCS table for non-RedCap UE is mandatory for RedCap UE, while the 256QAM MCS table and low SE MCS table are optional for RedCap UE.Proposal 5: The default CQI table for non-RedCap UE (i.e. Table 5.2.2.1-2 in TS 38.214) is also the default CQI table for RedCap UE.Proposal 6: The default CQI table for non-RedCap UE is mandatory for RedCap UE, while the 256QAM CQI table and low SE CQI table are optional for RedCap UE. |

[R1-2104554](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104554.zip) Other UE Complexity Reduction Aspects Nokia, Nokia Shanghai Bell

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| Proposal 1: There is no need to modify DCI fields/formats for RedCap UE supporting 1 DL MIMO layer.Proposal 2: There is no need to modify CSI measurement/reporting for RedCap UE with relaxed maximum number of DL MIMO layers.Proposal 3: MCS Tables 5.1.3.1-1 and 6.1.4.1-1 are the default tables for RedCap UE.Proposal 4: Low SE MCS Tables 5.1.3.1-3 and 6.1.4.1-2 can be optionally supported for RedCap UE.Proposal 5: CQI Table 5.2.2.1-2 is the default table for RedCap UE.Proposal 6: Low SE CQI Table 5.2.2.1-4 can be optionally supported for RedCap UE. |

[R1-2104619](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104619.zip) Discussion on other aspects of reduced UE complexity CMCC

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| Proposal 1: The default MCS table of RedCap UEs should be the same as the default one of legacy UEs.Proposal 2: The low SE MCS table can be optional supported for RedCap UEs. |

[R1-2104680](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104680.zip) Other Aspects of UE Complexity Reduction Qualcomm Incorporated

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| Observation 1: The CSI resource setting and CSI reporting setting of non-RedCap UE can be used as a baseline for RedCap UE. The contents and quantities of CSI report can be reduced as a result of RX branch number reduction and DL MIMO layer reduction.Observation 2: To facilitate frequency selective scheduling outside the active DL BWP, UE has to receive CSI-RS on an non-active DL BWP and handles potential collisions with CSI measurement on the active DL BWP. This leads to an increase in UE complexity and RS overhead.Observation 3: To facilitate frequency selective scheduling outside the active UL BWP, UE needs to transmit SRS on an non-active UL BWP, which increases UE’s complexity and RS overhead, and is not supported by NR R15/16.Proposal 1: FFS frequency selective scheduling outside active DL BWP of RedCap UE.Proposal 2: SRS transmission on non-active UL BWP is not supported by RedCap UE. |

[R1-2104713](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104713.zip) Discussion on modulation order and MIMO layers for RedCap ZTE, Sanechips

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| Proposal 1: The default MCS table of RedCap UEs should be the same as the default one of legacy UEs.Proposal 2: The low SE MCS table can be optional supported for RedCap UEs. |

[R1-2104914](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2104914.zip) On other complexity reduction features for RedCap Intel Corporation

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| Proposal 1:RedCap UEs support maximum of 1 or 2 DL MIMO layers and such capability is reported as part of UE capability reporting. Observation 1:Support of low SE MCS tables could be beneficial, especially for small packets in the DL. * However, it may not be justified to require mandatory support from RedCap UEs.

Proposal 2:For RedCap UEs, mandating support of low SE MCS table should be considered in parallel to consideration of mandating support of slot aggregation for PDSCH (FG 5-17a). |

[R1-2105114](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105114.zip) On relaxed maximum modulation order Apple

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| Proposal 1: Keeping Table 5.1.3.1-1 as default table for Redcap UEs during initial access. Proposal 2: Keeping the CQI table corresponding to the MCS Table 5.1.3.1-1 as default for Redcap UEs. |

[R1-2105319](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105319.zip) Other aspects for complexity reduction for RedCap UEs Samsung

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| Proposal 1: DCI format 1\_2 can be a starting point for the DCI design for relaxed MIMO layer. Proposal 2: RedCap UEs use the same MCS table as default table with non-RedCap UEs.Proposal 3: MCS Table 3 and corresponding CQI table 3 can be optionally supported by RedCap UE. |

[R1-2105570](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105570.zip) Discussion on relaxed maximum modulation order and relaxed MIMO layer Xiaomi

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| Proposal 1: The default MCS/CQI table for non-RedCap UEs is reused as the default MCS/CQI table for RedCaps. Proposal 2: * MCS/CQI table including 256 QAM is optional for RedCap
* Low-SE MCS/CQI table is optional for RedCap

Proposal 3: There is no need to modify the DCI format/ field for reduced MIMO layerProposal 4: There is no need to modify the CSI measurement/ report for reduced MIMO layer |

[R1-2105595](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105595.zip) MIMO aspects for RedCap NEC

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| Proposal:DL MIMO capability of TS 38.306 needs updateTP is provided as follows:

| **maxNumberMIMO-LayersPDSCH**Defines the maximum number of spatial multiplexing layer(s) supported by the UE for DL reception. Except for RedCap type, ~~F~~for single CC standalone NR, it is mandatory with capability signaling to support at least 4 MIMO layers in the bands where 4Rx is specified as mandatory for the given UE and at least 2 MIMO layers in FR2. For RedCap type with 2Rx, it is mandatory with capability signaling to support 2 MIMO layers. For RedCap type with 1Rx, only single layer is supported. If absent, the UE does not support MIMO on this carrier except for RedCap type, or the UE only supports single layer for RedCap type. | FSPC | CY | N/A | N/A |
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Proposal:Support of only single layer can be indicated by absence of the parameter maxNumberMIMO-LayersPDSCHProposal:Number of Rx branches of RedCap UE can be indicated implicitly by the parameter maxNumberMIMO-LayersPDSCHProposal:For better co-existence between RedCap and non-RedCap UE and scheduling flexibility of gNB, * RedCap UE supports any DMRS configuration
* RedCap UE with 1Rx supports any single antenna port
* RedCap UE with 2Rx supports any antenna port(s) up to two layers
* Existing tables to indicate antenna port(s) of DCI formats are reused
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[R1-2105706](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_105e_Review%5CallTdocs_R1-105e%5CR1-2105706.zip) Discussion on other aspects of UE complexity reduction for RedCap NTT DOCOMO, INC.

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| Proposal 1: Do not modify existing DCI fields/formats for relaxed maximum number of DL MIMO layersProposal 2: Do not modify existing CSI measurement/reporting for relaxed maximum number of DL MIMO layersProposal 3: Support default MCS table for non-RedCap UEs as default one for RedCap UEs |