3GPP TSG-RAN WG1 Meeting #104bis-e R1-210xxxx

e-Meeting, 12th – 20th April, 2021

**Agenda Item: 8.6.1.2**

**Title: FL summary #1 for reduced number of Rx branches for RedCap**

**Source: Moderator (Apple)**

**Document for: Discussion, Decision**

# Introduction

This document summarizes the contributions [3] – [31] made under the “Aspects related to reduced number of Rx branches” agenda item of the Rel-17 work item on support of reduced capability NR devices [1].

Earlier RAN1 agreements for this work item are summarized in [2].

The revised Redcap WID [1] contains the following objectives related to this agenda item:

|  |
| --- |
| * Specify support for the following UE complexity reduction features [RAN1, RAN2, RAN4]:   […]   * + Reduced minimum number of Rx branches:     - For frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports, the minimum number of Rx branches supported by specification for a RedCap UE is 1. The specification also supports 2 Rx branches for a RedCap UE in these bands.     - For frequency bands where a legacy NR UE (other than 2-Rx vehicular UE) is required to be equipped with a minimum of 4 Rx antenna ports, the minimum number of Rx branches supported by specification for a RedCap UE is 1. The specification also supports 2 Rx branches for a RedCap UE in these bands.     - A means shall be specified by which the gNB can know the number of Rx branches of the UE.   + 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.   […]   * Specify a system information indication to indicate whether a RedCap UE can camp on the cell/frequency or not; it shall be possible for the indication to be specific to the number of Rx branches of the UE. [RAN2, RAN1] |

Follow the naming convention in this example:

* RedCapRxFLS1-v000.docx
* RedCapRxFLS1-v001-CompanyA.docx
* RedCapRxFLS1-v002-CompanyA-CompanyB.docx
* RedCapRxFLS1-v003-CompanyB-CompanyC.docx

# Reporting of Number of Rx branches

RAN1#104e made the following agreements related to initial DL BWP:

|  |
| --- |
| Agreements:   * For reduced minimum number of Rx branches in FR1 and FR2 frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports:   + FFS: need for solutions to reduced PDCCH blocking   + FFS: need for reporting of UE antenna related information to gNB (e.g., # of panels, polarization, etc.)   + Information related to the reduction of the number of antenna branches is assumed to be known at the gNB (either implicitly or explicitly, to be FFS) |

In addition, a new objective was added in the revised WID [1] to specify a means by which the gNB can know the number of Rx branches of the Redcap UE. This issue was widely discussed in contributions [3][4][6][7][8][9] [10][11][12][13][14][15][16][18][19][21][23][24][27]

Table 1 summarized the proposed options to indicate the number of Rx branches of the Redcap UE:

**Table 1: Options to indicate the number of Rx branches at least for FR1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | Description | Companies | Motivations | Num. of Companies |
| Opt.1 | Using UE capability report explicitly or implicitly | Huawei [3], Vivo [6], CATT [7], MediaTek [9], Futurewei [11], Intel [15], Apple [16], Sharp [23],  Ericsson [10]/ Samsung [18]: (Using the capability parameter maxNumberMIMO-LayersPDSCH) | * Msg2/Msg4 coverage is not an essential issue for 1 Rx/2 Rx with TB scaling [3][6][7]. * Coverage for 1Rx/2Rx for wearable maybe simliar [3]. * No DL coverage enhancements are agreed for RedCap with minimum 1 Rx branch. For initial access, conservative scheduling, power boosting, TB scaling and/or HARQ-based retransmission for Msg.4 are all available to enhance the DL channel performance [6]. * The cost for supporting early identification during Msg1 transmission is in terms of increased PRACH OH in the cell due to partitioning of ROs, RACH resources, [15] * To reduce reporting overhead and to avoid unnecessary specification work [10] [16] | 10 |
| Opt.2 | Using Msg1 and/or Msg3, and MsgA | OPPO [4],  ZTE [12]  Nordic Semiconductor ASA [27] | * Improve the performane of Msg2/4 [4][12]. * If the number of Rx branches is not part of this early indication, the network would have to assume the UE has 1 Rx branch. In addition, the network would not be able reject connection from 1Rx UE during initial access [8]. * Support load balancing of RACH resources between REDCAP and non-REDCAP devices [8]. | 3 |
| Opt.3 | Configuration between Opt.1 and Opt.2 via SIB1 | CMCC [13],  LGe [19],  Nokia [8] (optionally configured) | * The need of differentiate 1 Rx/2 Rx UE maybe frequency and deployment scenario dependent [8] | 3 |

Based on the Table 1 above, clearly Opt.1 is the preferred approach by major companies. Hence, Question 1 was asked to address this open issue:

**Question 2-1: Can we agree the following proposal? If not, which modifications are needed?**

* **Using UE capability report (i.e., Opt.1) as baseline to indicate the number of Rx branches?** 
  + **FFS: Using earlier indication by Msg1 and/or Msg3, and MsgA (Opt.2)**
  + **FFS: The need of selection by SIB1 between earlier indication and UE capability report (Opt.3)**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI |  | Existing mechanism capability reporting is, of course, reused and default when early identification is not configured / not applicable for that UE. With the potential degradation in performance of Msg2/Msg4 resulting from using 1Rx branch, the network can configure early identification for those RedCap UEs or those which are experiencing poor conditions so that the appropriate amount compensation can be applied. Another FFS can be added to configure/enable early identification. |
| NordicSemi | N | Assuming that MSG1 would be supported for early indication of RedCap UEs (optionally) by gNB, restricting that RedCap-MSG1 to only 1Rx RedCap UEs could be easily supported by SIB1 signalling. In other words, 2Rx UE could follow legacy ROs and 1Rx UE could follow RedCap ROs. Therefore, we would see that there should not be an issue for UE to support both Option 1 and Option 2. |
| Sierra Wireless | N | It is too early to take this agreement before RAN2 concludes and may possibly be within RAN2’s responsibility. As Futurewei points out, the agreement is stating the obvious support for UE capabilities. But based on the RAN PL discussion it is clear that blocking or redirection 1RX RedCAP UEs based on UE capability alone was no sufficient which is why Sierra supports Opt3 as it has the most flexibility. |
| NEC | N | Capability reporting and access control specific to the number of Rx branches of the UE should be led by RAN2. |
| Qualcomm | Y | From RAN1 perspective, Opt. 1 is preferred. |
| Nokia, NSB | N | We think that both Options 1 & 2 should be supported. |
| CMCC |  | We think this is related to the early identification of Rx number. If the necessity of early dentification is not justified, then option 1 can be used. However, early identification can bring benefit for network efficiency in some cases, for example, when the number of RedCap devices is large, and both 1Rx and 2Rx device coexisted in the same network. In this case, if the coverage performance gap is obvious for 1Rx and 2Rx, awlays peform conservative scheduling of RedCap UEs will result in waste of network resource, so we think option 3 is better, that is to let gNB deciding. |
| DOCOMO | N | We agree with the proposal in principle from RAN1 perspective, but as pointed out by Sierra Wireless and NEC, this issue should be led by RAN2 |
| vivo | Y | We think the FL proposals is reasonable and support it.  Option 1 can be agreed as the baseline, while possibility to use early indication to distinguish 1Rx and 2Rx UEs can be further discussed |
| OPPO | N | Earlier identification of RedCap UE with 1 Rx can improve performance of Msg2/Msg4. Capability report is existing mechanism. It can be performed during or after initial access, but it is not for earlier indication. In our view, the essential issue is whether RedCap UE with 1 Rx should be earlier identified from RAN1 perspective. If yes, option 2 should be supported. |
| China Telecom | N | We think both option 1 and option 2 should be further studied. If early identification is supported, the number of antenna branches can be assumed to be known at the gNB via early identification either explicitly or implicitly for all bands. After initial access, if the number of Rx branches is still not known at gNB, UE capability report can be used to indicate the number of Rx branches. |
| Xiaomi |  | We think Opt1 can be a baseline, however, it might not be parallel options with Opt2/3, which means beyond capability report, Opt2 or 3 can still be supported, of course, we can FFS in next RAN1 meeting. |
| Sharp | Y | We agree with FL proposal. FFS does not preclude the option 2 and option 3. They can be discussed later if we have further outcome on early identification. |
| Samsung | Y with modification | The two FFS points are not needed. The fundamental function of early indication is not for Rx branches indication, but to differentiate RedCap UEs and non-RedCap UEs. It may not work when RedCap UEs support both 1 Rx branch or 2 RX branches. |
| ZTE,sanechips | N | Considering the impact on the network efficiency from antenna reduction, Option2 should be considered. |
| CATT | Y | From RAN1’s perspective, there is no strong motivation to identify the Rx number during the access since coverage is not a problem no matter for 1 Rx or 2 Rx UE. |

# Potential PDCCH Enhancement

Reducing the number of Rx branches degrades the link performance and coverage. Therefore, for a given PDCCH BLER-performance target, higher ALs may be needed for RedCap Ues to compensate for the coverage loss. Generally, the PDCCH blocking rate increases when higher Als are used. Hence, reducing the number of Rx branches may result in a higher PDCCH blocking rate. In general, the impact on PDCCH blocking performance from RedCap Ues would depend on various factors such as the number of Ues which need to be scheduled (may depend on the traffic), CORESET size (i.e., number of CCEs), number of PDCCH candidates, and PDCCH link performance/coverage (which affects the required aggregation level, AL), and relative fraction of RedCap Ues with reduced capability on number of Rx branches.

In contributions [3] [4] [5] [6] [7] [8] [10] [11] [12] [13] [14] [15] [16] [17] [18] [20] [23] [25] [26] [28], views on the necessity of PDCCH enhancement have been presented to enhance the PDCCH blocking rate. A few alternatives were proposed as listed in Table 2, mainly motivated by the use case where has a relatively larger fraction of Ues that are RedCap Ues with reduced capability for number of Rx branches or PDCCH capacity shortage due to the reduced BW and demanding CCE Als for Redcap devices.

On the other hand, athough SNR gap could be as large as 5~6 dB, e.g., between a 1Rx RedCap UE and a 4Rx non-RedCap UE, whether the overall PDCCH user blocking performance is impacted would be a function of the deployment and relative number for such RedCap Ues within all Ues in the cell. It was observed in [10] [8] that the number of simultaneously scheduled Ues is expected to be between 1 and 5 and the impact of reducing the number of Rx branches on PDCCH blocking probability is small. Hence, no solution of reducing PDCCH blocking rate enhance was proposed in [4] [6] [7] [8] [10] [15] [18] and [25].

**Table 2: View on PDCCH enhancement for Redcap**

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Description | Companies | # of Companies |
| Alt.1 | Reuse the existing DCI format, including Rel-16 DCI format 0\_2/1\_2 | OPPO [4], Vivo [6], CATT [7], Nokia [8], Ericsson [10], Intel [15], Qualcomm [17], Samsung [18], Panasonic [25] | 8 |
| Alt.2 | Introducing new Compact DCI(s) | Huawei [3], Futurewei [11], Qualcomm [17], Samsung [18], CEWiT [20], | 5 |
| Alt.3 | Introducing a group-wise DCI that can be used to schedule multiple Ues. | Huawei [3], CMCC [13], CEWiT [20], | 3 |
| Alt.4 | Support PDCCH link adaptation (e.g., RS resource for CSI measurement associated with CORESET) | Samsung [18] | 1 |
| Alt.5 | Multi-TB scheduling | Samsung [18], Intel [15], CEWiT [20], | 3 |
| Alt.6 | Configuring eparate CORESETs or Initial DL BWP for Redcap Ues | Spreadtrum [5], ZTE [12], Intel [15], ASUSTeK [28], Sharp [23] | 5 |
| Alt.7 | Joint optimization of RV cycling order and number of repetitions | Qualcomm [17], | 1 |
| Alt.8 | SPS-based and CG-based transmission in RRC connected state | Qualcomm [17], | 1 |
| Alt.9 | RACH-based or CG-based SDT in RRC inactive state | Qualcomm [17] | 1 |

**Question 3-1: Which alterative(s) among these listed in Table 1 are preferred and Why? Please share your views including any further modification on the listed options.**

* Note that the feedback is intended to be used to down select Alternatives (e.g., excluding alternative(s) that are only interested by one or two companies), such that in a next step during RAN1 104-bis e-meeting, RAN1 to focus on selected alternatives including establishing feasibility and identifying pros and cons to make progress:

|  |  |
| --- | --- |
| **Company** | **Comments/Reasoning** |
| FUTUREWEI | PDCCH blocking is in the scope of discussion as per the FFS. Compact DCI (format 1\_2) is an optional feature that is available to RedCap Ues. Compact DCI feature is least optional and could be mandatory for RedCap Ues. We are okay to discuss whether we need to modify the existing format or to create a new format. We lean towards making small modifications to the existing format, in the same spirit as rel. 17 UL coverage enhancement. |
| NordicSemi | We would focus discussion on the following techniques:  Alt1: Compact DCI x\_2 could be used by default by RedCap Ues   * FFS further RedCap-specific simplifications to DCI x\_2   Alt 5: Could be optionally supported by RedCap UE, if designed in 60GHz AI in R17  Alt 6: One dedicated CORESET can be supported in RRC Connected and dedicated BWP could be somewhere else than CORESET#0. However, during initial access all Ues of a 100MHz cell are packed to first 2-3symbols of a slot and 20MHz (with 30kHz it is 16-24CCE). Therefore, proposal should be focused on initial access and CORESETs in frequency domain. |
| Sierra Wireless | None of the solutions are essential functionality and may overly complicate the Redcap UE for little benefit. |
| NEC | PDCCH enhancement is not in the WID. |
| Qualcomm | As we commented earlier in the GTW session, Alt 1 is our preference. Alt 7 is a sub-topic of Alt 1, and the RV sequence selection (i.e. [0 3] vs [0 2]) was discussed in R16 CR for compact DCI formats (0\_2, 1\_2).  Alt. 8 and Alt. 9 aim to reduce the signaling overhead of PDCCH, which are applicable to RedCap Ues as appropriate. |
| Nokia, NSB | Existing solutions can be used to mitigate potential PDCCH blocking so we don’t think any new solution needs to be specified. Furthermore, based on our analysis, PDCCH blocking does not seem to be an issue with RedCap UE. |
| CMCC | Alt.6 is an effective method if separate initial DL BWP is adopted.  Compact DCI(Alt.1 or 2 can be further studied) can be considered, since it is supported by the spec already.  And alt.3 and 5 can also be considered. |
| DOCOMO | As mentioned in the beginning of this section, PDCCH blocking rate increases when higher Als are used, which comes from the reduced number of Rx branches for RedCap Ues. Therefore, we think it is in the scope, similar to the potential BWP enhancement for the reduced UE BW discussed in AI8.6.1.1.  We think whether existing features (e.g. compact DCI) are enough or not should be discussed at first, and if deemed necessary, we are open to discuss any enhancements for reducing the PDCCH blocking rate. |
| Vivo | It is debatable whether PDCCH enhancement for blocking reduction is in scope or not as the WID does not include this objective.  Technically, during the study item, we studied the reduced blind decodes and there was no consensus about its impact to PDCCH blocking rate. However, we did not have an recommendation to solve the PDCCH blocking rate issue purely due to reduced Rx but not the reduced blind decodes.  From the list of alternatives that FL has summarized, we think alt1 can be supported as the baseline as there is no good reason to not allow Redcap Ues to implement the existing solutions. |
| OPPO | PDCCH enhancement is out of scope in the WID. We do not think it is necessary to introduce new solutions addressing PDCCH blocking rate, since some existing solutions can be used, e.g. BWP, search space, CORESET configuration. |
| Xiaomi | We share the same reason with DOCOMO and some other companies that handling of the PDCCH blocking is within the scope.  As for the detailed solutions, we are OK to discuss Opt.1, Opt.5, Opt.8 and Opt.9. |
| Sharp | The proposal aims to find some solutions to mitigate PDCCH blocking which is an FFS of the agreement in RAN1#104e. Therefore, in our view, it is in the RAN1’s discussion scope.  Alt.1 and Alt.6 can be discussed. Alt.6 needs to be focused on initial access. As one Rel-15 basic feature, type 1 CSS without dedicated RRC configuration and other CSS expect type 3 can be any OFDM symbols of a slot. Therefore, CORESETs in time domain (i.e separate search spaces) should be taken into consideration to address the PDCCH blocking issue. |
| Samsung | We think increased PDCCH blocking rate due to reduced Rx branches is an issue for RedCap UEs. We suggest to agree on the need for PDCCH blocking rate reduction first in this meeting. The details, such as alternatives including whether or not existing methods are sufficient can be FFS. In addition to the need for higher CCE AL, large number of connectivity and low spectrum efficiency due to increased PDCCH overhead are additional reasons cause the PDCCH blocking issue. |
| ZTE,Sanechips | Alt.6. For serious blocking scenarios, separate CORESET or search space can be configured to reduce impact on non-RedCap NR UEs.  Additionally, the Table2 should be used in Question 3-1 instead of Table1. |
| CATT | Alt.1.  We think PDCCH blocking is not a serious issue, and PDCCH enhancement is not essential to support RedCap (out of scope, more precisely). Adopting current Rel-15/16methods should be enough. |

# MCS and CQI Tables

RAN1#104e made the following agreements related to MCS and CQI table for Redcap devices:

|  |
| --- |
| 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 |

Table

Description automatically generated

Figure 1: MCS Tables

In contribution [5] [8] [11] [18], views on MCS and CQI tables support for Redcap devices have been presented. Companies’ positions were summarized in Table 3:

**Table 3: View on MCS table support**

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Description | Companies | # of Companies |
| Opt.1 | Low-SE MCS table is mandatory for Redcap UE | Spreadtrum [5], Futurewei [11] (at least for 1 Rx capable UE), | 2 |
| Opt.2 | Keep same as normal UE (i.e., MCS table 1 is the default Table and MCS Table 3 is optionally supported.) | Nokia [8], Samsung [18] | 2 |

In [11], differences between low-SE MCS table (i.e., MCS Table 3) and MCS table 1 were analyzed. It was observed that there are six more indices available below 0.12 (lowest code rate of the normal MCS table). The ratio between the lowest code rates in each table is 4. While TB scaling and the lower SE table each provide a maximum factor of 4 decrease in code rate, the lower SE table provides four additional levels; allowing the network more control to fine tune the coding rate. In addition, TB scaling and the lower SE table can be coupled; providing up to a factor of 16 decrease in code rate. This benefit in network flexibility was further motivates to make the lower SE table the default MCS table for RedCap Ues to address performance for initial access. It also pointed out in [11] that for certain network configurations, a RedCap UE and legacy UE can be scheduled with the same DCI for Msg2. As one consequence, a RedCap UE is required to translate the signaled MCS index to an index to the lower SE table.

On the other hand, contribution [8] emphasized that from the coverage results in TR 38.875, it is seen that MCS Table 1 is sufficient. In addition, during initial access, legacy Ues would only use MCS Table 1. Therefore, if MCS Table 3 is the default table for RedCap UE, it would be necessary to differentiate RedCap UE starting from Msg1. This is against the WI objective that RedCap UE can be identified in Msg1 and/or Msg3, and Msg A if supported, including the ability for the early indication to be configurable by the network. In [8], it was additionally acknowledged that for some services (e.g., industrial sensor requires commercial service availability of 99.99% and video surveillance requires reliability of up to 99.9%), it would be beneficial to use MCS Table 3 to improve coverage. Therefore, support for MCS Table 3 would be beneficial for some RedCap use cases or Ues. However, there is no need to make Table 3 support mandatory for all RedCap Ues.

**Question 4-1: Which one between Opt.1 and opt.2 in Table 3 is preferred? If none of them, please describe the preferred option in ‘comment’ column. As usual, please provide brief justification for your preference.**

* Opt.1: Low-SE MCS table is mandatory for Redcap UE
* Opt.2: Keep same as normal UE (i.e., MCS table 1 is the default Table and MCS Table 3 is optionally supported.)

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Comments** |
| FUTUREWEI |  | As per Chair guidance, this will be discussed in a different agenda item. |
| NordicSemi | Opt 1 | But, we ACK that Opt 1 is feasible only if RedCap Ues are early identified by gNB. This means that in practice both Low-SE and Regular tables would be mandatory for REDCAP UE in practice. |
| Sierra Wireless | None | Although our view is option1 – as per comments online – this is a UE capability discussion and can be discussed much later in the work item. |
| NEC |  | Same comment as FUTUREWEI |
| Qualcomm |  | It can be discussed later in R17 UE features for RedCap. |
| Nokia, NSB |  | Same view as Futurewei |
| CMCC | Option 2 | We agree that this can be discussed under the modulation order agenda |
| DOCOMO |  | Same comment as FUTUREWEI |
| vivo |  | Agree with QC |
| OPPO |  | Same view as Futurewei |
| China Telecom |  | Same view as FUTUREWEI. It would be discussed in relaxed maximum modulation order agenda in next meeting. |
| Xiaomi |  | Same consideration with Futurewei and other companies. This issue can be discussed later. |
| Sharp |  | Same view as FUTUREWEI. |
| Samsung | Opt.2 | As Chair’s guidance, this will not be discussed in this agenda. Technically, we think option 2 is sufficient. |
| ZTE,Sanechips | Opt.2 | Low-SE MCS table is mainly used for URLLC with the BLER requirement of 10-5, so such low SE MCS is defined to guarantee reception reliability. Although reduced number of Rx branches lead to performance degradation, the amount of performance degradation is limited. High-SE MCS table has the MCS entries with sufficient low SE, which can be applicable for the reduced number of Rx branches. Hence the existing specifications can be reused for RedCap UEs and low-SE table can be optionally supported according to different use cases. |
| CATT |  | It can be discussed later (in another agenda), not in this meeting. |

In NR, there are 3 CQI tables defined with one-to-one correspondence to the configured MCS table. Similarly, Companies were invited to provide inputs regarding the CQI table support for Redcap UEs in the following question.

**Question 4-2: Which option is preferred regarding CQI table support for Redcap devices? If none of them, please describe the preferred option in ‘comment’ column. As usual, please provide brief justification for your preference.**

* Opt.1: CQI table corresponding to low-SE MCS table is mandatory for Redcap UE
* Opt.2: Keep the same as normal UE (i.e., CQI table one corresponding to MCS table 1 is the default Table and CQI table one corresponding to MCS Table 3 is optionally supported.)

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Comments** |
| FUTUREWEI |  | As per Chair guidance, this will be discussed in a different agenda item. |
| NordicSemi | Opt 1 |  |
| Sierra Wireless | None | Although our view is option1 - as per comments online – this is a UE capability discussion and can be discussed much later in the work item. |
| NEC |  | Same comment as FUTUREWEI |
| Qualcomm |  | It can be discussed later in R17 UE features for RedCap. |
| Nokia, NSB |  | Same view as Futurewei |
| CMCC | Option 2 | We agree that this can be discussed under the modulation order agenda |
| DOCOMO |  | Same comment as FUTUREWEI |
| vivo |  | Agree with QC |
| OPPO |  | Same view as Futurewei |
| China Telecom |  | Same view as FUTUREWEI. It would be discussed in relaxed maximum modulation order agenda in next meeting. |
| Xiaomi |  | Same consideration with Futurewei and other companies. This issue can be discussed later. |
| Sharp |  | Same view as FUTUREWEI. |
| Samsung | Opt.2 | This can be discussed in other agenda later. Technically, we think option 2 is sufficient. |
| ZTE,Sanechips | Opt.2 | Same with Question 4-1 |
| CATT |  | It can be discussed later (in another agenda), not in this meeting. |

# Need of DL Coverage Recovery

Based on the revised WID [1], the minimum number of Rx branches is 1 for Redcap device on all of the FR1 bands. In TR 38.875, the observation of coverage evaluation can be summarized in Table below [29].

|  |
| --- |
| * DL coverage recovery for RedCap UE is needed for FR1 only * For RedCap UE with 1 Rx branch and reduced antenna efficiency, the need for coverage recovery depends on the frequency bands and DL PSD: * For carrier frequency of 4 GHz with DL PSD 24 dBm/MHz, coverage recovery may be needed for the downlink channels of Msg2, Msg4 and PDCCH CSS. A small or moderate compensation can be considered, where the square brackets indicate that the exact amount will depend on the techniques, scenarios, etc.:   - [1 dB] for PDCCH CSS  - [2-3 dB] for Msg4  - [6 dB] for Msg2 without TBS scaling. It is noted that coverage loss for Msg2 can be compensated by using the existing TBS scaling technique.  - For other carrier frequencies or DL PSD of 33 dBm/MHz, coverage recovery is not needed for the downlink channels if the target for coverage recovery is based on the MIL of the bottleneck channel for the reference NR UE.   * For RedCap UE with 2 Rx branches and reduced antenna efficiency, the need for coverage recovery also depends on the frequency bands and DL PSD: * For carrier frequency of 4 GHz with DL PSD 24 dBm/MHz, coverage recovery may be needed for the downlink channels of Msg2. A small or moderate compensation can be considered, where the square brackets indicate that the exact amount will depend on the techniques, scenarios, etc.:   - [1 dB] for Msg2 without TBS scaling. It is noted that coverage loss for Msg2 can be compensated by using the existing TBS scaling technique.   * For other carrier frequencies or DL PSD of 33 dBm/MHz, coverage recovery is not needed for the downlink channels if the target for coverage recovery is based on the MIL of the bottleneck channel for the reference NR UE. |

This was further summarized in Table below [11]

**Table 4: Coverage recovery observations in [29]**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2 Rx branches | | 1 Rx branch | |
| Channel | 4GHz, and DL PSD 24 dBm/MHz | not at 4GHz or using DL PSD 33 dBm/MHz | 4GHz, and DL PSD 24 dBm/MHz | not at 4GHz or using DL PSD 33 dBm/MHz |
| PDCCH |  |  | [1 dB] needed |  |
| PDSCH | [1 dB] needed |  | [2-3 dB] Msg4, [6 dB] Msg2 |  |
| PUSCH | [~3 dB] needed | [~3 dB] needed | [~3 dB] needed | [~3 dB] needed |

A few contributions [11] [17] [21] [22] [24] [26] [28 discussed the necessity of DL coverage enhancements especially for 1 Rx capable Redcap devices with the following proposals:

* One contribution [11] proposed to make two optional UE features to be mandatory to improve the PDSCH coverage especially in initial access phase, one is Low-SE MCS table and the other is PDSCH repetition feature.
* In [17], it was observed that a sufficient number of solutions exist commonly for Redcap and non-Redcap UEs, including TB scaling for msg2 PDSCH or msgB PDSCH, Low MCS, PDSCH repetition, Power boosting of gNB, VRB-to-PRB mapping, large AL for PDCCH. DL coverage recovery can be triggered by earlier identification.
* One contribution [21] proposed to investigate the msg2, msg4, and PDCCH coverage enhancement. BLER results for Msg2 with and without TBS scaling were provided in [21] and it was observed that TBS scaling only may not be sufficient to compensate the observed 6 dB coverage gap.
* In [22], it was proposed that RAN1 to confirm the following:
  + Whether or not DL PSD = 24dBm/MHz should be considered in normative work.
  + Confirm if antenna loss up to 3dB in both DL and UL due to compact form factor should be considered and if DL coverage recovery for Msg2 and PDCCH CSS and UL coverage recovery for Msg3/PUSCH should be supported by the spec.
  + Discuss whether to adopt different level of coverage recovery (including no coverage recovery) for 1Rx and 2Rx RedCap UE, if DL coverage recovery is supported
* One contribution [26] proposed to clarify whether DL coverage recovery is in the scope of RedCap WI.
* One contribution [28] proposed to support repetition of CORESET#0/CommonCORESET in RB-sets of a single wide carrier/BWP was proposed.

**Question 5-1: Whether or not DL coverage enhancement should be considered based on current WID scope? If yes, please also explain the justification and list the preferred solution in Comment column.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| FUTUREWEI | N | Although RAN discussed DL coverage enhancement, they decided not include DL coverage enhancement in the WID scope. With the 1Rx branch feature, there will be substantial degradation in performance even when the UE is in coverage. The question is how RAN1 should compensate for this degradation in DL performance. |
| NordicSemi | Y, but | We are fine to discuss DL coverage enhancements, but discussion should be referred to RAN1#105, such that all companies have chance to contribute to the topic. |
| Sierra Wireless | N | This is very clearly not in the scope of the WI. |
| NEC | N | From discussion in RAN#91, it is clear that DL coverage *enhancement* is out of the scope of the WI. |
| Qualcomm | Y | The observations/conclusions of R17 RedCap SI indicated that DL coverage recovery is needed in FR1 (e.g. PDCCH and PDSCH during initial access) for 1 RX UE.  Since the minimum number of RX branches is 1 for R17 RedCap UE, it is necessary to study the DL coverage recovery/enhancement for 1 RX UE by identifying the solutions available for non-RedCap UE, which can be re-used by R17 RedCap UE in FR1. |
| Nokia, NSB | Y | It would be good to discuss DL coverage recovery and whether this can be mitigated via implementation or additional compensation will be needed. |
| CMCC | N | Agree with FUTUREWEI. |
| DOCOMO | N | DL coverage recovery is out of the scope based on the discussion in RAN#91e |
| vivo | N | Agree with FUTUREWEI, Sierra Wireless, NEC, CMCC, DOCOMO,… |
| OPPO | Y | 1 Rx is confirmed in the revised WID for the frequency bands where a legacy NR UE is required to be equipped with a minimum of 4 Rx antenna ports. For the RedCap UE with 1 Rx in these frequency bands, DL coverage has higher loss. DL coverage loss should be addressed in some cases, since it is related to the introduction of 1 Rx of RedCap UE, which is one of main aspects of reduced capability. |
| China Telecom | N | Same view as FUTUREWEI. |
| Xiaomi | Y | Same view with QC.  In our view, identifying existing solutions to compensate the DL coverage loss due to Rx reduction is within the WID scope. In this issue, only existing coverage enhancement solutions are considered. No new or No Redcap-specific DL coverage enhancement will be introduced. |
| Samsung |  | We are open to discuss, especially to enhance the coverage of PDCCH CSS. But we think there is no issue for Msg 2 with TB scaling factor. |
| ZTE,Sanechips | N | It is out of the scope and the existing technologies can be applied if needed. |
| CATT | N | Not essential and out of scope. |

# Access Control for Redcap

In the updated WID, one objective was added to allow system information indicating whether a RedCap UE can camp on the cell/frequency, and the indication can specific to 1Rx or 2Rx.

|  |
| --- |
| * Specify a system information indication to indicate whether a RedCap UE can camp on the cell/frequency or not; it shall be possible for the indication to be specific to the number of Rx branches of the UE. [RAN2, RAN1] |

Contribution [3][13][19] discussed aspects realizing this objective of access control for Redcap UEs. In [3], different mechanisms were mentioned for the network to indicate whether the network allows the UE’s access, including indications in MIB or SIB1 or load balancing mechanism during the initial access procedure, or during paging procedure, use of 2 more spare bits in PBCH payload or using sparse bits in DCI that schedules SIB1. In [19], different alternatives were discussed depending on the bits number of signalling for access control, such as Bar RedCap UEs (regardless of the number of Rx branches), 1-Rx only, or 1-Rx only for bands requiring 4 Rx branches. Using sparse bits in DCI that schedules SIB1 is preferred by [3] [19] due to potential power saving benefit. It was proposed in [19] that access control signalling in SIB should provide the flexibility to indicate per band whether a RedCap UE with specific number of Rx branches of the UE can camp on the cell/frequency. In [13], it proposed that System information can indicate the conditions that RedCap UEs or RedCap UEs with specific number of Rx branches are allowed to camp on the cell/frequency.

On the other hand, it should be noted that the issue of access control is being discussed in RAN WG2 as leading work group on this objective. To avoid duplicate efforts and considering the fact that the objective is tasked to RAN2 as leading WG, it may be prudent to wait for RAN WG2 to make further progress first. In addition, the access and earlier identification were typically managed to be handled in dedicated Redcap agendas.

**Conclusion 6-1: On the issue of access control for Redcap UEs, RAN1 waits for RAN2 further progress and continue discussion in other Redcap agendas starting from RAN1 105 meeting.**

* **If ’no’, please kindly explain which aspects you think RAN1 need to work on in this meeting and why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI |  | As per Chair guidance, this will be discussed in a different agenda item. |
| NordicSemi | OK |  |
| Sierra Wireless | yes | As per Chair guidance, this will be discussed in a different agenda item. |
| NEC | Yes |  |
| Qualcomm | Y | Access control is discussed in RAN2 and other working groups. RAN1 should wait for their decisions/agreements. |
| Nokia, NSB | Y |  |
| CMCC | Y |  |
| DOCOMO | Y |  |
| vivo | Y | Agree with QC |
| OPPO | Y |  |
| China Telecom | Y |  |
| Xiaomi | Y |  |
| Sharp | Y |  |
| Samsung |  | Access control should be discussed in AI 8.6.2 on RAN1 aspects for RAN2-led features for RedCap in next RAN1 meeting. It’s independent from reduced Rx branches. |
| ZTE,Sanechips |  | Whether the reserved bits in the DCI for SIB1 can be used for access control should be discussed by RAN1. |
| CATT | Y |  |

# Earlier Identification of Redcap Devices

The revised WID lists the following objectives

|  |
| --- |
| * Specify functionality that will enable RedCap UEs to be explicitly identifiable to networks through an early indication in Msg1 and/or Msg3, and Msg A if supported, including the ability for the early indication to be configurable by the network. [RAN2, RAN1] |

In contributions [3] [4] [6] [15] [19] [24] [27], views on redcap device type efinition and realizing the earlier identification of RedCap Ues have been presented, as summarized in Table below:

Table

|  |  |
| --- | --- |
| Companies | Views |
| Huawei [3] | The one RedCap UE type has only maximum UE channel bandwidth including in the minimized set of basic capabilities |
| OPPO [4] | Using Msg1 and FFS on Msg3 |
| Intel [15] | Configurable between Msg1/Msg3 |
| Lge [19] | * Separate RO in time/frequency for Redcap devices, * Configurable by SIB1 on Msg1 or Msg3 or both and even inclusion of number of Rx branches |
| Nordic Semiconductor ASA [27] | * Using Msg1. * Support replicating Ros to multiple RB-sets based on configuration within one RB set. * Using Msg3 to indicate number of Rx branches if both 1 Rx and 2 Rx Redcap devices are allowed by network. |

Similar as ‘Access control’ topic, the ‘earlier identification’ was handled in another dedicated agenda (i.e., AI 8.6.2), which was void in this meeting. In addition, the issue of earlier identification control is being discussed in RAN WG2 as leading work group on this objective.

**Conclusion 7-1: No further discussion on ‘earlier identification’ of Redcap device in RAN1 104 bis e-meeting.**

* **If the answer is ’no’, please kindly explain which aspects you think RAN1 need to discuss in this meeting and why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| NordicSemi | OK |  |
| Sierra Wireless | yes | As per Chair guidance, this will be discussed in a different agenda item. |
| NEC | Yes |  |
| Qualcomm | N | We think early indication by RedCap UE can be discussed in this meeting, since it is associated with the PHY designs that enable early identification of RedCap Ues by NW, which can be de-coupled from the access control and other upper layer aspects.  The necessity for early indication/identification can be justified (at least) by the following example, assuming RedCap UE is allowed to access the NW:  • When the initial UL BWP of non-RedCap UE is wider than the max BW of RedCap UE, early indication by msg1 is necessary during initial access, which can inform NW about the presence of RedCap UE.  • After NW knows the presence of RedCap UE, it can determine an appropriate UL grant for the msg3 transmission (or retransmission), which is aligned with the reduced capabilities (e.g. BW) of RedCap UE.  • Without PHY support for early indication/identification, RedCap UE is likely to experience constant failures during initial access, even though it is allowed to access the NW. |
| Nokia, NSB | Y |  |
| CMCC | N | We think early identification is related to reporting of number of Rx branches, it can be discussed with section 2 together. |
| DOCOMO | Y |  |
| vivo | Y | The relevant WID objective is the following and RAN2 led   * Specify functionality that will enable RedCap Ues to be explicitly identifiable to networks through an early indication in Msg1 and/or Msg3, and Msg A if supported, including the ability for the early indication to be configurable by the network. [RAN2, RAN1]   So it should belongs to the AI 8.6.2 “RAN1 aspects for RAN2-led features for RedCap” which is restricted for this meeting, no discussion expected. |
| OPPO | N | In the revised WID, the following are in the scope.   * *A means shall be specified by which the gNB can know the number of Rx branches of the UE.* * *Specify functionality that will enable RedCap Ues to be explicitly identifiable to networks through an early indication in Msg1 and/or Msg3, and Msg A if supported, including the ability for the early indication to be configurable by the network. [RAN2, RAN1]*   Discussions are needed in RAN1 for the issue of earlier identification of RedCap UE. It has impacts on performance of Msg2/4, which is related to the reduced 1 Rx branch. |
| China Telecom | N | We are fine to discuss the early identification in section 2 in this meeting. |
| Xiaomi |  | We think early identification is not the focus in this meeting. We can discuss this issue in later phase. But we are open to only discuss the need of early indication for Rx branch. |
| Sharp | Y |  |
| Samsung | Y | Earlier identification should be discussed in AI 8.6.2 on RAN1 aspects for RAN2-led features for RedCap in next RAN1 meeting. It’s independent from reduced Rx branches. |
| ZTE,Sanechips | N | Earlier identification especially for msg1 should be discussed as soon as possible by RAN1, since RAN2 discussion is limited by the decision. |
| CATT | Y |  |

# Other aspects

**Cell selection**

* P1: One contribution proposed to introduce specific RSRP thresholds for Redcap device which are configured by gNB for SSB and UL carrier selection for performing random access

**DCI size reduction**

* P2: One contribution [16] proposed to consider capturing in physical specification TS 38.212 that Redcap UE always assumes MCS/NDI/RV of TB2 is not presence to avoid the need of RRC signaling of ‘*maxNrofCodeWordsScheduledByDCI’.*

**Access barring**

* P3: It was proposed in [24], that barring of RedCap UEs could be based on DL channel status, instead of simply based on number of Rx branches

**Question 8-1: Which of the proposals in the list above (P1, P2, P3) are important and need to be discussed in the RAN1 104-bis e-meeting to make progress? What other aspects/proposal need to be added for discussion?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | P2 can be discussed if time allows |
| vivo | P1/P3 are more RAN2 issues. P2 can be discussed in RAN1 but not urgent for this meeting. |
| OPPO | P1 is related to DL coverage loss due to reduced Rx branch. It can be discussed if time allows. |
| Samsung | DCI size reduction can be considered as an alternative for PDCCH blocking rate reduction. P1 and P3 are not relevant to reduced Rx branches for RedCap.  In addition, we addressed the FFS in previous meeting: “FFS: need for reporting of UE antenna related information to gNB (e.g., # of panels, polarization, etc.) ”. In our view, there is no need to report additional UE antenna related information to gNB. |

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