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

**e-Meeting, May 10th – 27th, 2021**

**Agenda Item: 8.6.1.2**

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

**Source: Apple**

**Document for: Discussion, Decision**

# Introduction

This feature lead (FL) summary concerns the Rel-17 work item for support of reduced capability (RedCap) NR devices [1]. Earlier RAN1 agreements for this work item are summarized in [2].

This document summarizes contributions [3] – [26] submitted to agenda item 8.6.1.2 and relevant parts of contributions [27] – [40] submitted to agenda item 8.6.2 and captures the following email discussion for the RedCap WI.

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| //This one is to use NWM – please use ***RAN1-105-e-NWM-NR-R17-RedCap-02*** as the document name  [105-e-NR-R17-RedCap-02] Email discussion regarding aspects related to reduced number of Rx branches – Hong (Apple)   * 1st check point: 5/21 * 2nd check point: 5/25 * Final check: 5/27 |

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

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| * 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.   […]   * 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]   Notes:   * Uplink coverage enhancement solutions specified in the NR Coverage Enhancement WI (NR\_cov\_enh) shall be assumed to be available also to RedCap UEs by default (with small modifications for RedCap UEs if found necessary). |

The issues in this document are tagged and colour coded with High priority or Medium priority.

RAN1#104e has already made the following agreements regarding reduced number of Rx branches for RedCap [2]:

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| 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) |

For information, the same content was documented in R1-2105112 for reference.

**Please enter your company name in square brackets in the beginning of your answer in each feedback form, for example: [Apple]**

# Reporting of Number of Rx branches

RAN1#104-bis e-meeting made the following agreements related to reduced number of Rx branches:

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| Agreements**:**   * At least using UE capability report according to the existing framework to indicate (implicitly or explicitly) the number of Rx branches * FFS: whether/how to support earlier indication of Redcap UEs with # Rx branches by Msg1 and/or Msg3, and MsgA   + FFS: Network configurability of early indication of the number of Rx branches via SIB1, if supported |

One of the FFS identified in RAN1#104bis e-meeting is to discuss whether/how to support earlier indication of Redcap UEs with # Rx branches by Msg1 and/or Msg3, and MsgA. In addition, if supported, whether introduces network configurability mechanism. Table 1 summarized different views regarding support of earlier indication of #Rx branches by Msg1 and/or Msg3, and MsgA:

**Table 1: Support earlier identification of number of Rx branches**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Companies | Motivations | # Companies |
| Yes | Futurewei [4], Nokia [8], CMCC [9], ZTE [11], OPPO [12], Xiaomi [18], Sierra Wireless [32], | * Avoid conservative scheduling for Msg2/Msg4 and mitigate latency degradation for 1-Rx device [4][8][11] [12]. * Flexible and Finer cell access control [8][9] * Reduce PDCCH blocking durning initial access [11] * Apply DL coverage recovery for 1-Rx Redcap device [18] [32] | 7 |
| No | Ericsson [3], Huawei [5], vivo [6], CATT [7], Intel [13], Apple [14], Samsung [16], Sharp [20], DoCoMo [21], Panasonic [22], MediaTek [23], InterDigital [24], Nordic [26], Spreadtrum [29] | * Avoid unnecessary PRACH overhead and partitioning of PRACH resources, especially considering that PRACH partitioning has been discussed and agreed for a number of other purposes such as coverage enhancement, slicing, NTN, and small data transmission, group A/B and 4-step vs. 2-step RACH [3][5][6][7][13][16][21][24][26].   **On DL coverage compensation motivation**:   * No DL coverage enhancement was agreed for Redcap with 1-Rx branch [6][7][14][22][29]. * For RedCap UE with 1Rx, it does not always mean its channel condition is poor [6][14][26]. * The DL coverage gap between 1-Rx and 2-Rx for Redcap is smaller compared to that between Redcap and non-Redcap UEs [5]. * Techniques (e.g., Power boosting, TB scaling and/or HARQ-based retransmission) are all available to enhance the DL channel performance during the initial access.can for all RedCap UEs regardless of the number of UE’s Rx branches [3][5][6][14][16].   Others:   * Even assuming all RedCap UEs may be scheduled assuming 1Rx (“worst case”), the overall impact from this constraint would not be significant since the density of non-RedCap UEs in the cell is expected to dominate the overall loading in the cell [13]. * The early indication of the number of Rx branches in Msg1 and/or Msg3, and MsgA can be interpreted as there is more than one RedCap UE type, therefore — as the WID mandates to specify only one RedCap UE type — the early indication should be used only to indicate whether the UE is RedCap or not [3]. * Avoid the unnecessary specification work [3] | 14 |

Based on the Table 1 above, clearly it is the preferred option by major companies to not support earlier identification of number of Rx branches.

**FL1 High Priority Question 2-1: Can we agree the following conclusion? If not, please clarify the justification.**

* **Conclusion: No consensus to support earlier identification of number of Rx branches in Msg1/Msg3/MsgA for Redcap UE.**

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| **Company** | **Y/N** | **Comments** |
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It remains open regarding how to indicate the number of Rx branches by UE capability signaling, i.e. implicitly or explicitly. Table 2 summaried different views from companies.

**Table 2: Indication of Rx branches number through UE capability**

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| --- | --- | --- | --- | --- |
|  | Description | Companies | Reasoning | # Companies |
| Opt.1 | Implicitly via the existing capability parameter maxNumberMIMO-LayersPDSCH. | Vivo [6], CATT [7], Nokia [8], ZTE [11], Apple [14], Samsung [16], Sharp [20], | * It was agreed in WID that the number of Rx branches is the same as the maximum number of MIMO layers for RedCap UEs | 7 |
| Opt.2 |  |  |  |  |

From the above, reusing the existing capability parameter *maxNumberMIMO-LayersPDSCH* to implicitly indicate the number of Rx branches to network receives all of support.

**FL1 High Priority Proposal 2-1:**

* The number of Rx branches for RedCap is implicitly indicated by the existing capability parameter *maxNumberMIMO-LayersPDSCH*.

Companies were invited to provide comment or modification to make progress:

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| **Company** | **Y/N** | **Comments** |
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# DCI formats for Redcap

RAN1#104-bis e-meeting made the following agreements related to DCI formats support for Redcap UEs:

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| Agreements:   * Reuse the existing DCI formats 0\_x/1\_x (including Rel-16 DCI format 0\_2/1\_2) applicable to Redcap devices as a starting point.   + FFS Whether and how potential modification on fields of existing DCI formats is considered to reduce PDCCH block issue, if any.   + FFS: Which DCI formats are mandatory for the RedCap UEs to support. |

On the DCI format support for Redcap UEs (i.e., 2nd FFS), the views are categorized in Table 3:

**Table 3: Views on DCI formats for Redcap UEs**

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| --- | --- | --- | --- | --- | --- | --- |
| # | DCI formats  (M: Mandatory; O: Optional) | | | Companies | Reasoning | # Companies |
| DCI 0\_0/1\_0 | DCI 0\_1/1\_1 | DCI 0\_2/1\_2 |
| Alt.1 | M | M | O | Ericsson [3], Huawei [5], Vivo [6], Intel [13] | * Same as legacy [3][5]. * DCI formats 0\_2/1\_2 may not be typically supported by gNBs and neither are the DCI format size reduction expected to be as significant as feasible for URLLC scheduling (since a majority of the DCI format size reduction for DCI formats 0\_2/1\_2 come from compression of the FDRA bit-field) [13]. | 4 |
| Alt.2 | M | M | M | Futurewei [4] |  | 1 |
| Alt.3 | M | O | O | ZTE [11] |  | 1 |
| Alt.4 | M | O | M | Samsung [16], Sharp [20], Panasonic [22] | * DCI x\_2 can further reduce PDCCH overhead [16][20]. * gNB can configure DCI format x\_2 to be same as DCI format x\_1 if needed [16][20]. | 3 |

Other views on DCI formats support for Redcap are briefly captured as follows:

* Contribution [24][25] proposed to mandate DCI format 0\_2/1\_2 for Redcap UEs.
* Contribution [7] considered to at least mandate DCI format 0\_x for Redcap UEs as in legacy system and down select one from the DCI x\_1 and DCI x\_2.
* Contribution [8] proposed that RedCap UE supports at least DCI formats 0\_0, 0\_2, 1\_0 and 1\_2.

All of companies proposed to mandate DCI 0\_0/1\_0 for Redcap UE to receive SI/Paging and Msg2 [6], to avoid mismatch between Redcap and non-Redcap UEs during initial access when initial DL/UL BWP is shared [22] and to handle uncertainties during RRC reconfiguration period [5].

**FL1 High Priority Proposal 3-1:**

* Same as for legacy UEs, Redcap UE is mandated to support DCI format 0\_0/1\_0.

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| **Company** | **Y/N** | **Comments** |
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**FL1 High Priority Question 3-1:**

Regarding DCI format 0\_1/1\_1 and DCI format 0\_2 and 1\_2, which option below should be adopted for Redcap? Please provide brief justification for your preference.

* Opt.1: Both are mandatory.
* Opt.2: DCI format 0\_1/1\_1 are mandatory as in legacy. DCI 0\_2/1\_2 are optionally supported.
* Opt.3: DCI format 0\_2/1\_2 are mandatory. DCI 0\_1/1\_1 are optionally supported.

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| **Company** | **Which Option?** | **Comments/Justification** |
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There was another FFS aspect for DCI format regarding the potential modification on the fields of existing DCI formats to reduce PDCCH block issue, if any. This was discussed in a few contributions and the following was proposed:

* P1: Contribution [7] [8] [12] [13] [17] [23] indicated modification on fields of existing DCI formats is NOT considered at least for PDCCH blocking issue.
* P2: Contributions [4] proposed the following for non-fallback DCI formats, mainly motivated by the reduced capabilities e.g., up to 2 Rx branches and no need of CA/DC support.
* For non-fallback UL DCI format, at least following field(s) can be removed for RedCap:
  + Carrier indicator, UL/SUL indicator, Precoding information and number of layers, CBG transmission information (CBGTI), 2nd downlink assignment index, PTRS-DMRS association, SCell dormancy indication
* For non-fallback DL DCI format, at least following field(s) can be removed for RedCap
  + Carrier indicator, UL/SUL indicator, Modulation and coding scheme for TB1, New data indicator for TB1, Redundancy version for TB1, SCell dormancy indication, CBG transmission information (CBGTI), CBG flushing out information (CBGFI).
* P3: Contribution [10] proposed to introduce new RRC parameters to indicate the RV sequence used for PDSCH/PUSCH transmission in compact DCI formats applicable to RedCap UE.
* P4: Contribution [14] proposed to capture in physical specification TS 38.212 that Redcap UE always assume MCS/NDI/RV of TB2 is not presence to avoid the need of RRC signaling.
* P5: Contribution [16] proposed to reduce MCS field by 1-2 bits for DCI format x\_2 for RedCap UEs due to small TB size. This is similar as eMTC.

**FL1 High Priority Question 3-2:**

* Which proposal(s) among these listed are preferred and Why? Please share your views including any further modification on the listed proposals to make it acceptable.

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| **Company** | **Which Option** | **Comments** |
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# On PDCCH Blocking Issue

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 contribution [16], it was observed based on evaluation results that compact DCI is not sufficient to reduce PDCCH blocking issue caused by reduced Rx branches and a new solution is therefore needed. In addition, PDCCH blocking problem was also considered as an issue in contributions [9][10][11] [15] [18] [19] [21] [26] and the following was proposed:

* + P1: Separate (initial) DL BWP [9]
  + P2: Multi-UE scheduling [9]
  + P3: Multi-TB scheduling [9]
  + P4: Support RACH-based or CG-based SDT for RedCap UE in RRC inactive state [10]
  + P5: For initial access, a dedicated CORESET or search space for RedCap UEs could be defined to reduce PDCCH blocking [11] [15] [26].
  + P6: Support link adaptation on PDCCH to improve the spectrum efficiency of RedCap with reduced minimum number of Rx branches [16].
  + P7: For at least RedCap UEs, support repetition of CORESET#0/CommonCORESET in frequency domain within wide configured gNB carrier [26].

On the other hand, although 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 [3] 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. On the other hand, it was argued in [26] that simulations in study item phase have not taken into account the fact that in 20MHz BW overlapping with SSB/CORESET#0, gNB operates also initial access plus broadcast in addition to unicast traffic and often with high AL, which clearly increases the PDCCH blocking. Contribution [3][6][8][13][17][23] indicates that no need to introduce solutions for reducing PDCCH blocking rate.

**FL1 High Priority Question 4-1:**

* Is there a need to introduce solution for reducing PDCCH blocking rate for Redcap? If yes, which alterative(s) among these listed [P1~P7] are preferred and why? Please share your views including any further modification on the listed options to make it acceptable.

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| **Company** | **Yes/ No** | **Comments/Reasoning** |
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# Other aspects

Some other enhancements were brough up by companies as follows:

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| **#** | Description | Contributions |
| P1 | Multi-slot repetition for PDSCH is considered as a mandatory feature for RedCap UEs during feature discussions. | Futurewei [4] |

**FL1 High Priority Question 5-1:**

* Is ’P1’ need to be added for discussion or discussed in the later UE features stage together with others?
* Please also comment if any other proposals were missed in this summary or need to be added for discussion in RAN1 105 e-meeting under this agenda.

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| **Company** | **Comments** |
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# References

1. RP-210918 “Revised WID on support of reduced capability NR devices”, RAN#91e, Nokia, Ericsson.
2. R1-2104027 RAN1 agreements for Rel-17 NR RedCap Rapporteur (Ericsson)
3. [R1-2104180](C:\\Users\\wanshic\\OneDrive - Qualcomm\\Documents\\Standards\\3GPP Standards\\Meeting Documents\\TSGR1_105\\Docs\\R1-2104180.zip) Reduced number of Rx branches for RedCap Ericsson
4. [R1-2104189](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104189.zip) Discussion on RX Branch Reduction for RedCap UEs FUTUREWEI
5. [R1-2104284](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104284.zip) Reduced number of Rx branches for RedCap Huawei, HiSilicon
6. [R1-2104366](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104366.zip) Discussion on reduced number of Rx branches vivo, Guangdong Genius
7. [R1-2104527](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104527.zip) Discussion on reduced number of Rx branches CATT
8. [R1-2104544](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104544.zip) Aspects related to reduced number of Rx branches Nokia, Nokia Shanghai Bell
9. [R1-2104617](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104617.zip) Discussion on reduced number of Rx branches CMCC
10. [R1-2104678](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104678.zip) RX Branch Reduction for RedCap UE Qualcomm Incorporated
11. [R1-2104711](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104711.zip) Discussion on reduced number of UE Rx branches ZTE, Sanechips
12. [R1-2104783](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104783.zip) Discussion on reduced number of UE Rx branches OPPO
13. [R1-2104912](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2104912.zip) On reduced number of Rx branches for RedCap Intel Corporation
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18. [R1-2105568](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105568.zip) Aspects on reduced number of Rx branches Xiaomi
19. [R1-2105594](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105594.zip) Discussion on aspects related to reduced number of Rx branches NEC
20. [R1-2105636](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105636.zip) Discussion on reduced minimum number of Rx branches Sharp
21. [R1-2105704](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105704.zip) Discussion on reduced minimum number of Rx branches for RedCap NTT DOCOMO, INC.
22. [R1-2105728](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105728.zip) Aspects related to reduced number of Rx branches Panasonic Corporation
23. [R1-2105737](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105737.zip) On reduced number of Rx branches for RedCap UEs MediaTek Inc.
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26. [R1-2105883](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_105\Docs\R1-2105883.zip) On aspects related to reduced number of Rx branches Nordic Semiconductor ASA
27. [R1-2104287](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104287.zip)    RAN1 aspects of RedCap UE type and identification           Huawei, HiSilicon
28. [R1-2104369](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104369.zip)    Higher layer support for RedCap          vivo, Guangdong Genius
29. [R1-2104431](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104431.zip)    Discussion on early indication for RedCap UE    Spreadtrum Communications
30. [R1-2104530](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104530.zip)    Discussion on higher layer support of RedCap   CATT
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32. [R1-2104562](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104562.zip)    Design consideration for Higher layer support of RedCap                  Sierra Wireless, S.A.
33. [R1-2104620](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104620.zip)    Discussion on higher layer support of RedCap UE              CMCC
34. [R1-2104714](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104714.zip)     Higher layer support of Reduced Capability NR devices    ZTE, Sanechips
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36. [R1-2104853](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104853.zip)    Discussion on RAN1 aspects for RAN2-led features for RedCap        China Telecom
37. [R1-2104915](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2104915.zip)     On RedCap UE types: Definition, access control, and identification Intel Corporation
38. [R1-2105220](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2105220.zip)      UE identification and access control for RedCap                 Lenovo, Motorola Mobility
39. [R1-2105638](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2105638.zip)    RAN1 aspects for RAN2-led features for RedCap                 Sharp
40. [R1-2105885](file:///C:/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_105/Docs/R1-2105885.zip)     On RedCap UE early identification        Nordic Semiconductor ASA