3GPP TSG-RAN WG1 Meeting #106-e R1-21xxxxx

e-Meeting, 16th – 27th August 2021

**Agenda Item: 8.6.1.2**

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

**Source: Moderator (Apple)**

**Document for: Discussion, Decision**

# Introduction

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

This document summarizes contributions [3] – [21] submitted to agenda item 8.6.1.2 and captures this email discussion on reduced number of Rx branches:

|  |
| --- |
| [106-e-NR-R17-RedCap-02] Email discussion regarding aspects related to reduced number of Rx branches – Hong (Apple)   * 1st check point: August 19 * 2nd check point: August 24 * Final check: August 27 |

The issues in this document are tagged and color coded with High Priority or Medium Priority.

In this round of the email discussion, please comment on the issues tagged ‘FL2’ before Tuesday 17th August 23:59 UTC.

Follow the naming convention in this example:

* *RedCapBwFLS1-v000.docx*
* *RedCapBwFLS1-v001-CompanyA.docx*
* *RedCapBwFLS1-v002-CompanyA-CompanyB.docx*
* *RedCapBwFLS1-v003-CompanyB-CompanyC.docx*

If needed, you may “lock” the discussion document for 30 minutes by creating a checkout file, as in this example:

* Assume CompanyC wants to update *RedCapBwFLS1-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapBwFLS1-v003-CompanyB-CompanyC.checkout*
* CompanyC checks that no one else has created a checkout file simultaneously, and if there is a collision, CompanyC tries to coordinate with the company who made the other checkout (see, e.g., contact list in Annex).
* CompanyC then has 30 minutes to upload *RedCapBwFLS1-v003-CompanyB-CompanyC.docx*
* If no update is uploaded in 30 minutes, other companies can ignore the checkout file.
* Note that the file timestamps on the server are in UTC time.

In file names, please use the hyphen character (not the underline character) and include ‘v’ in front of the version number, as in the examples above and in line with the general recommendation (see slide 10 in [R1-2106403](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106403.zip)), otherwise the sorting of the files will be messed up (which can only be fixed by the RAN1 secretary).

To avoid excessive email load on the RAN1 email reflector, please note that there is NO need to send an info email to the reflector just to inform that you have uploaded a new version of this document.

# On PDCCH Blocking Rate Reduction

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.

Table 1 summarized companies views on introducing solutions for reducing PDCCH block rate caused by reduced number of Rx branches.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Companies | Reasoning | Companies # |
| Alt.1: No new solutions | Ericsson [4],  Vivo [5],  Nokia [6],  CATT [9],  OPPO [11],  InterDigital [17] | * Considering a typical operation region of 1 to 5 simultaneously scheduled UEs, the impact of reducing number of Rx branches on PDCCH blocking probability in FR1 and FR2 frequency bands is small. [4] * Link budget analysis shows that, in most deployment scenarios, UEs will not require high PDCCH aggregation levels even with reduced Rx braches and reduced antenna efficiency [4][6]. * No severe PDCCH blocking issue was identified in study item phase. [5] * Compact DCI format can be utilized to reduce the blocking rate already. [5][6][9] * The PDCCH block rate can be controled by gNB scheduler e.g., power boosting of PDCCH to reduce the AL, separate CORESETs/SS for Redcap and non-Redcap UEs. [6][9][11] * For RedCap UE, traffic may be delay-tolerant and thus can tolerate PDCCH blocking. [6] | 6 |
| Alt.2: Additional CORESET in separate initial DL BWP can be configured for Redcap UE to reduce PDCCH blocking rate during initial access | ZTE [7],  Apple [15],  Nordic [10],  CMCC [13],  LGe[14],  Lenovo [20] | * For medium coverage, PDCCH blocking rate increased to 21.6% for 25% Redcap UEs and 27.5% for 50% Redcap UEs and hence needs to be reduced if more than 25% RedCap UEs access the network. [7] * It was also noted in [10] that this solution was being discussed under AI 8.6.1.1 and can continue discussing over there. | 6 |
| Alt.3: Support link adaptation on PDCCH | Samsung [8] | * For medium coverage, when RX branches is reduced from 4 to 1, PDCCH blocking rate can be increased by by approximately Infx, 362x, and 11.6x, for UE sizes of 2, 4, and 8, respectively [8]. * Similar as eMTC, link adaptation on PDCCH can be considered to improve coverage of PDCCH with SE gain. The link adaptation SE gain for PDCCH can be observed as comparable to that for PDSCH, considering the equivalent channel [8]. * Provide RS resource for CSI measurment/report assoicatd with CORESETs in different frequency location. [8] | 1 |
| Alt.4: Support RACH-based or CG-based SDT for RedCap UE in initial BWP. | Qualcomm [12], CMCC [13], | * For RedCap UEs with semi-static or periodic traffic patterns, SPS and configured grant can be applied to reduce the overhead of PDCCH. In NR R17, small data transmission (SDT) is specified for RRC inactive UEs. The RACH-based or CG-based transmission can reduce the PDCCH blocking rate in initial DL BWP. [12] | 2 |
| Alt.5: For initial access, dedicated search space for RedCap UEs could be defined to reduce PDCCH blocking in case of shared initial DL BWP. | CMCC [13], | * If the initial DL BWP is shared by RedCap and non-RedCap devices, dedicated search space for Msg2 and Msg4 can provide TDM chances for RedCap and non-RedCap even they are associated with CORESET#0, it can help reduce PDCCH blocking. | 1 |
| Alt.6: Multi-TB scheduling | CMCC [13], | * discussed in beyond 52.6GHz WI, with one DCI scheduling multiple PDSCHs/PUSCHs, less PDCCHs will be transmitted, so it can also be adopted for RedCap UE to reduced possible PDCCH blocking | 1 |
| Alt.7: Multi-UE activation of SPS or UL grant Type 2 configuration | CMCC [13] | * Since the data traffic are the same or similar among different UEs for some use cases, such as industrial wireless sensors, when SPS or UL grant Type 2 configuration is configured for such UEs, the activation DCI can be shared by multiple UEs to reduce PDCCH transmission, thereby reducing the probability of PDCCH blocking. | 1 |

**Discussion #1**

**FL1 High Priority Questions:**

* **Q 2-1: Should we leave Alt.2 above to be discussed under AI 8.6.1.1 to avoid duplicated efforts?**
* **Q 2-2: Among the remaining alternatives i.e. Alt.3/4/5/6/7, which ones can be further discussed? Please provide a motivation/justification for your answer.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Example | Q 2-1: Yes  Q2-2: Alt 3/4/5/6/7 | …. |
| Huawei, HiSilicon | Y for Q 2-1  No critical issues for Q 2-2 | Although open for other issues quested by Q 2-2 but the spec impact should be minimized and most of them we consider can be either discussed in UE feature session (e.g. the SDT feature can be used by RedCap UEs) or up to network configurations. Thus, overall do not see critical issues that have to be discussed in RedCap unless the naturally inherited DCI simplification by reduced number of Rx branches and MIMO layers. |
| Xiaomi | Q 2-1: Yes  Q2-2: Alt.4/Alt.6 | For Q2-2, Alt.4 and Alt.6 are optional feature for normal UE, they can also be supported by RedCap. |
| vivo | Q 2-1: Yes  Q 2-2: None | We should keep in mind that no significant PDCCH blocking issue was identified during SI therefore it is not a critical issue to be solved.  Additional CORESET in separate initial DL BWP can be used to reduced the PDCCH blocking issue, if any. And some existing solutions, e.g. compact DCI format, can also be useful.  Given the above, the additional solutions such as Alt.3/4/5/6/7 are not well justified and the standardization efforts are significant. |
| CMCC | Q 2-1: Y  Q 2-2: Alt.4/5/6 | We think Alt.5 is a gNB implement method, no spec. influence involved.  Alt. 4 and 6 can be discussed during UE feature phase, the benefit of PDCCH blocking reduction needs to be considered for UE feature introduction.  Alt.7 is one new feature, and we agree that it may need more work. Considering high UE density for industry deployment, it can help reducing PDCCH signalling overhead and PDCCH blocking. It can be considered in the feature release. |
| Panasonic | Q2-1: Yes  Q2-2: None | On Alt.3, our understanding is up to gNB implementation using CSI feedback. Alt 4/5/6/7 has some specification impacts and these are optimization, which is not necessary considering the remaining TUs. |
| OPPO | Q2-1: Yes  Q2-2: None | It is not common understanding that there is PDCCH blocking issue with the existence of RedCap UEs. And it is not clear whether additional solutions are necessary, considering many existing solutions can be used. |
| LG | Q 2-1: Yes  Q 2-2: None | We don’t see there is a critical issue on the PDCCH blocking rate caused by the reduced number of Rx branches. If PDCCH blocking rate issue should be addressed, Alt 2 can be discussed as a viable solution under AI 8.6.1.1. With Alt 2 and the existing DCI formats (without modification), the PDCCH blocking rate can be controlled sufficiently by gNB. |
| Qualcomm | Q2-1: Yes  Q2-2: Alt 4 |  |
| Spreadtrum | Q 2-1: Yes  Q 2-2: it depends. | For Q 2-1, Alt.2 was being discussed in AI 8.6.1.1 for offloading purpose in the last meeting, and we think it can be continue discussed in AI 8.6.1.1.  For Q 2-2, it depends on the discussion of Alt 2, the remaining alternatives i.e. Alt.3/4/5/6/7 can be comeback latter, if necessary. |
| Lenovo, Motorola Mobility | Q2-1: Yes  Q2-2: alt.4/alt.5 | Alt.4 is not fully motivated by reducing PDCCH blocking, but it does provide such benefit.  Alt.5 is one simple candidate to reduce blocking in case additional CORESET is not configured. |
| CATT | Q 2-1: Y  Q 2-2: N | Alt.2 is discussing in AI 8.6.1.1 now.  For Alt.3~7, we think most of them are not supported/optional even for non-RedCap UEs. Though we think they may be used by RedCap UE, they should remain not supported/optional for RedCap UE, if applicable. We do not see strong need for RedCap-specific optimization/enhancement to these features. |
| Samsung | Q 2-1: Yes  Q2-2: Alt3 | We think there is need to consider solutions to reduce PDCCH blocking rate, due to i) large PDCCH overhead (higher AL), and ii) large connectivity and coexistence with legacy UEs.  Alt3 can help avoid unnecessary high AL to reduce PDCCH overhead, thus reduce PDCCH blocking rate. In addition to PDCCH blocking issue, spectrum efficiency is also an issue caused by reduced RX branches. For RedCap UEs, the resources for PDCCH increases, while resources used for TB decreases (given the low target data rate). The link adaptation of PDCCH is as important as link adaptation for data considering the same level of resource overhead..  For Alt4, Alt6, Alt7, we are open to consider those features for Redcap, but we think common features can be considered for RedCap and non-RedCap UEs. No specific features dedicated to RedCap UEs is needed.  For Alt5, it can be considered if separated iBWP is not configured. |
| DOCOMO | Q2-1: Yes  Q2-2: Alt 4/6 | Alt 4/6 can be discussed during Re-17 UE feature discussion and no additional specification effort is expected. |
| ZTE, Sanechips | Q2-1: Y  Q2-2: alt.5 | Alt2 in frequency domain and alt5 in time domain are similar methods to reduce the blocking by determine different resource location. And the gNB can configure different method according to the different scenario of resource utilization.  Alt.4, Support RACH-based or CG-based SDT for RedCap UE in initial BWP, can be discussed together with other UE features. |
| Nokia, NSB | Q2-1: Yes  Q2-2: None | Based on our analysis, PDCCH blocking is not expected to be an issue with RedCap UE. In addition, if necessary, existing methods can be used to significantly reduce PDCCH blocking (e.g. additional CORESET or search space).  Therefore, we don’t see the need to introduce new solution to specifically address PDCCH blocking. |
| FUTUREWEI | Q 2-1: Y  Q 2-2: Alt 4/5/6 | Alts 4 & 6 are related to feature discussion. Alt 5 seems to be relevant to AI 8.6.1.1 |
| Nordic | Q 2-1: Y  Q 2-2: N |  |
| Ericsson | Q 2-1: Y | Q 2-2:   * Alt. 4 and 6 can be discussed as part of Rel-17 UE feature list discussion. * Alt. 3 and 7 should not be considered in Rel-17 due to the required effort to introduce these solutions. * Alt. 5 may be discussed with low priority. |
| Sharp | Q2-1: Yes  Q2-2: Alt.5 | Agree with ZTE and FUTUREWEI’s views on alt.5. |
| IDCC | Q2-1: Yes | We do not see strong reason to consider other solutions with spec impact. |
| Intel | Q 2-1: Yes  Q 2-2: None at this point; pls. see comments | **On Q 2-2:**   * Alt 4 can be considered as part of UE features for RedCap.   For the rest, although some of the them could be beneficial, are not warranted at this stage of the WI, considering that we are not optimizing for high connection density of RedCap UEs in Rel-17 and neither is there any serious issue identified with PDCCH coverage or blocking performance for RedCap. |
| China Telecom | Q 2-1: yes  Q2-2: none | We agree with leaving Alt.2 to be discussed under AI 8.6.1.1 for avoiding duplicated efforts. And we think there is no need to discuss among the other remaining alternatives. |

Moderator Summary of Discussion #1

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| --- | --- | --- | --- | --- |
|  | Description | Yes | No | Num. of Companies |
| 1 | Leaving Alt.2 to be discussed under AI 8.6.1.1 | HW, Xiaomi, vivo, CMCC, Panasonic, OPPO, LG, Qualcomm, Spreadtrum, Lenovo, CATT, Samsung, DOCOMO, ZTE, Nokia, FUTUREWEI, Nordic, Ericsson, Sharp, IDCC, Intel, China Telecom |  | Yes: 22  No: 0 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | Description | Yes | No | Num. of Companies |
| 1 | Alt.1: No new solutions | HW, vivo, Panasonic, OPPO, LG, CATT, Nokia, Nordic, IDCC, Intel, China Telecom |  | 12 |
| 2 | Alt.3 | Samsung | Ericsson | 1 |
| 3 | Alt.4 | Xiaomi, CMCC, Qualcomm, Lenovo, DOCOMO, FUTUREWEI |  | 6 |
| 4 | Alt.5 | CMCC, Lenovo, ZTE, FUTUREWEI, Ericsson (low priority), Sharp |  | 5 |
| 5 | Alt.6 | Xiaomi, CMCC, FUTUREWEI |  | 3 |

To make the discussion more focus, FL propose to focus on the following alternatives in the 2nd round discussions:

* Alt.1: No new solution to reduce PDCCH blocking rate under AI 8.6.1.2.
* Alt.4: Support RACH-based or CG-based SDT for RedCap UE in initial BWP.
* Alt.5: For initial access, dedicated search space for RedCap UEs could be defined to reduce PDCCH blocking in case of shared initial DL BWP.

**FL2 High Priority Questions:**

* **Q 2-3: Among Alt.1/4/5, which ones can be agreeable?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Alt 1 | For Alt 4, if any technical issue is to be addressed, it should be discussed in SDT WI. |
|  |  | Alt 5 needs to be further clarified, if RedCap UEs are not going to share the search space with non-RedCap UEs during initial access, what is the motivation to share the initial DL BWP? Even if there is such a motivation, can gNB configure a separate initial DL BWP for RedCap UEs which has shared frequency location and BW with initial DL BWP for non-RedCap UEs, but different CORESET/SS? |
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# DCI Formats for Redcap UEs

In RAN1#104e and RAN1#104bis-e meetings, the following agreements on reduced minimum number of Rx branches were reached [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)   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. |

In RAN1 #105 e-meeting, extensive discussions were carried out on a variety of issues e.g., how to report number of Rx branches and DCI format support for Redcap Ues. The following was agreed at the end of discussions [2]:

|  |
| --- |
| **Agreement:**   * **Redcap UE is mandated to support at least DCI format 0\_0/1\_0.**   **Conclusion**   * No consensus to support early identification of the number of Rx branches in Msg1/Msg3/MsgA for Redcap UE in Rel-17   Agreement:  Regarding DCI format 0\_1/1\_1 and DCI format 0\_2 and 1\_2,   * DCI format 0\_1/1\_1 are mandatory as in legacy. DCI 0\_2/1\_2 are optionally supported. |

There are different views on the necessity to remove or optimize these DCI fields for Redcap Ues. The following was proposed by companies on this regard:

|  |  |
| --- | --- |
| P1 [3] | Antenna port (s) field in DCI for RedCap can be modified for relaxed maximum number of DL MIMO layers. |
| P2 [3] | DCI format 2\_x can be optionally supported and DCI format 3\_x is not supported for RedCap Ues. |
| P3 [5,15, 16, ] | * Non-fallback DCI for Uplink Scheduling:   + Carrier indicator,   + Precoding information   + CBG transmission information (CBGTI),   + 2nd downlink assignment index,   + PTRS-DMRS association,   + Scell dormancy indication. * Non-fallback DCI for Downlink Scheduling:   + Carrier 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). |
| P4 [8] | * Support reduction of MCS field for non\_fallback DCI format for RedCap Ues by 1 or 2 bits with configurable entries. |
| P5 [10] | * If RedCap Ues mandatorily support dynamic PDSCH and PUSCH repetition and if early identification of Redcap Ues is enabled by gNB, consider reusing SUL bit in fall-back DCI formats to indicate PDSCH/PUSCH repetition configured in SIB1. |

However, on P3, several contributions [6, 7, 9, 10,14,17,18] argue that DCI fields that are not necessary for RedCap UE can already be reduced to 0 bit by configuration and no need to removing these fields specially for Redcap as proposed above. Regarding the size reduction of Antenna Port(s) field (e.g., P1), contribution [9,18] observed that field size reduction for Redcap with 2 Rx is not possible and there is otential one bit reduction for UE with 1 R branch, which is marginal from coverage perspective and is not well justified by the required standard impact.

**Discussion #1**

**FL1 High Priority Question:**

* **Q 3-1: On P3, should we capture them or a subset of these fields explicitly in TS 38.212 for Redcap?**
* **Q 3-2: Regarding P1, P2, P4 and P5, which should be further discussed for Redcap? Please provide a motivation for your answer.**

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| **Company** | **Y/N** | **Comments** |
| Example | Q 3-1: Yes  Q 3-2: P1, P3, P4 | …. |
| Huawei, HiSilicon | Q 3-1: unclear  Q 3-2: P1 and P2 | Is the question Q 3-1 meaning to capture/specify those (subset of) fields explicitly to address to RedCap or explicitly specify that they are not used for RedCap?  P1 is naturally possible due to MIMO layers reduction. P2 can be discussed if there is additional spec impact required or if there is a need to support V2X. P4 and P5 has impact on existing features that a RedCap UE can possibly use, e.g. a RedCap UE can use full MCS range and SUL without them; otherwise there would be scheduling/deployment restriction for RedCap UE. |
| Example | Q 3-1: NO  Q 3-2: None | For Q3-1, in current NR, whether include these field in the DCI is based on the configuration. In our understanding, for RedCap, NW will not configure these features and these fields will not be included in DCI accordingly. Therefore, we think there is no need to explicitly capture them in TS 38.212. |
| vivo | Q 3-1: To discuss and decide which fields are not applicable to Redcap Ues and capture them explicitly.  Q 3-2: Open to discuss P1 | Q3-1, For those fields not-applicable to RedCap devices, we prefer to capture them explicitly in the specification.  Q3-2: P2/P4/P5 does not seem to be necessary. |
| CMCC | Q 3-1: Not needed  Q 3-2: P2 | For Q3-1, we need to decide which features are not supported by RedCap, then gNB will not configure such function, and such fields will not present.  For Q3-2, as summarized by FL, the benefit of one or two bits reduction in DCI size is marginal from coverage perspective. DCI format 2\_x can be optionally supported for group common signalling. Sidelink function has not been discussed for RedCap during this release, so DCI format 3\_x is not supported for R17 RedCap Ues. |
| Panasonic | Q3-1: No  Q3-2: P1 | On Q3-1, our view is also these bits are reduced by the configurations.  On Q-3-2, we are also ok not to discuss P1 as one bit optimization is limited. |
| OPPO | Q3-1: No  Q3-2: P1 and P2 | For Q3-1, Share the same view that the bits in Non-fallback DCI can be reduced by configuration. There is no need to explicitly capture them in TS 38.212.  For Q-3-2, We are open to further discuss P1 and P2 for Redcap. |
| LG | Q 3-1: No  Q 3-2: None | gNB may not provide the parameters regarding the fields on P3 that are not needed for RedCap Ues. Therefore, we don’t see the need for capturing them explicitly. |
| Qualcomm | Q 3-1: Open to discuss  Q3-2: P1, DCI 2\_x and 3\_x can be optional for RedCap UE | DCI 2\_6 is useful for UE power saving in C-DRX, which should be supported by RedCap UE |
| Spreadtrum | Q 3-1: No  Q 3-2: P2 | For Q 3-1, for RedCap Ues with limited capabilities, those related and configurable fields can be naturally configured to 0 bit, additional descriptions may not necessary.  For Q 3-2, DCI format 2\_x are used for different features, e.g. power saving, SFI, coexistence with URLLC and so on, since the supported features are under discussion, then the supported DCI format 2\_x can be FFS. For DCI format 3\_x, it is related to V2X, since whether V2X can be supported by RedCap is under discussion in RAN1 and RAN2, then this DCI format is unclear for RedCap for now. |
| Lenovo, Motorola Mobility | Q3-1: No  Q3-2: None | Legacy signalling supports the configuration of the fields in the DCI.  The motivation is not strong enough to reduce other fields. |
| CATT | Q 3-1: N  Q 3-2: N | For Q 3-1, we think the current specification already support that these DCI fields are naturally become zero bit, determined by the corresponding RRC configuration.  For Q 3-2:   * For P1, the bit reduction and coverage improvement are marginal as pointed out by many companies. * For P2, it is related to RedCap UE capability discussion. * For P4, we already agreed to reuse current MCS tables. * For P5, it is not only related to RedCap UE capability (dynamic repetition), but also a little confusing to us. Does RedCap UE not support SUL? (Current WID only states that CA, DC and BW larger than maximum RedCap UE BW are not supported). |
| Samsung | Q 3-1: No  Q 3-2: P1, P4 | For P3, legacy rule can be reused. We don’t see overhead on RRC configuration to indicate 0 bits for these fields.  P1 and P4 have the similar motivation, the bit-length of fields can be reduced due to unused entries from corresponding tables. |
| DOCOMO | Q 3-1: No  Q 3-2: None | Q3-1: No special handling is necessary as supported by current spec  Q3-2: P1/P4 – Expected gain is marginal and hence such optimization is no necessary. P2 can be discussed in UE capability discussion. P5 is out of WID scope. |
| ZTE, Sanechips | Q 3-1: N  Q 3-2: P1 | For Q3-1, these DCI fields are compatible with RedCap Ues. Their bitwidth can change based on RedCap UE capabilities. So there is no need to explicitly capture them in TS 38.212.  For P1, the bitwidth of antenna port field can be reduced by 1 bit for 1Rx RedCap Ues.  For P2, optional support of DCI format 2\_x has been agreed in RAN1#105e. And the support of DCI format 3\_x is can be discussed together with other UE features for RedCap Ues.  For P4, reusing current MCS table is enough for RedCap UE and we do not see the necessity of reducing MCS field.  For P5, it is not necessary. |
| Nokia, NSB | Q 3-1: No  Q 3-2: None | On P3, there is no need to explicit capture them as the fields can be configured based on RedCap UE capabilities.  For DCI 2\_x and 3\_x (P1), we can discuss them as part of UE capabilities.  For P2, P4, P5, we prefer to not support such small optimization. |
| FUTUREWEI | Q 3-1: N  Q 3-2: P2 | For clarification, is 2-x optional?  Regarding P5, we should have separate discussion of mandatory support of DL repetition first. We generally support that, but have reservations on not being able to optionally support SUL as it is a coverage enhancing feature |
| Nordic | Q 3-1 N  Q 3-2 none | For example, TB 1 will not be present automatically if UE can be configured with at most 4 layers, etc.  For Q-3-2 we agree that P2 and P5 need to be first discussed in features. At CATT, yes, secondary UL carrier belongs to wideband operations and despite not being mentioned in WID, we prefer NOT to support. Moreover, WID says “at least at least carrier aggregation, dual connectivity and wider bandwidths” so clearly in scope.  P1 and P4 are small optimizations of non-fall-back DCI format size, which is not worth of specification effort. |
| Ericsson | Q 3-1: No  Q 3-2: None | Q 3-1: As the FL mentioned in the summary, these can already be reduced to 0 bit by configuration. The gNB must anyway respect what the UE is capable of. Otherwise, the UE will reject the entire configuration message and perform an RRC reestablishment.  Q 3-2:   * P1 and P4: Reducing a bit width for these fields result in only marginal gain in terms of PDCCH link performance, while affecting scheduling flexibility which can impact overall system performance. For example, reducing MCS field by 1 bit already removes 16 MCS candidates which can result in unnecessarily inefficient scheduling. * P2 can be discussed in a later stage related to UE feature discussion. * P5: We should first discuss whether the feature is mandatory or not. |
| Sharp | Q 3-1: Y  Q 3-2: Open to discuss P1 and P2. | Q3-1: at least for MCS/NDI/RV of TB1, we prefer to explicitly specify they are absent for RedCap. Or not, it seems RedCap UE would expect to receive the RRC parameter to determine whether these DCI fields are absent or not. |
| IDCC | Q3-1: No  Q3-2: None |  |
| Intel | Q 3-1: No  Q 3-2: None at this point, pls. see comments | **On Q 3-1:**   * Existing specs already allow for omission of bit-fields in non-fallback DCI formats if related features are not configured.   **On Q 3-2:**   * P2 can be discussed as part of UE features for RedCap.   The rest are not sufficiently motivated at this point in time since neither of PDCCH coverage or blocking have been identified as serious issues for RedCap and optimization of 2~3 bits in DCI format size would not have any perceptible effect on coverage/blocking performance. |

Moderator Summary of Discussion #1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Description | Yes | No | Num. of Companies |
| 1 | P1 | Huawei, OPPO, Samsung, ZTE, Sharp | Xiaomi, LG, Lenovo, CATT, DCM, Nokia, FUTUREWEI, Nordic, Ericsson, IDCC, Intel, | Yes: 5  No: 11 |
| 2 | P2 | Huawei, CMCC, OPPO, Spreadtrum, FUTUREWEI, Sharp, Qualcomm (to discuss), | Xiaomi, Vivo, LG, Lenovo, CATT, DCM, Nokia, Nordic, Ericsson, IDCC, Intel | Yes (or to discuss): 7  No: 11 |
| 3 | P3 | Vivo, Sharp, Apple | Xiaomi, CMCC, Panasonic, OPPO, LG, Spreadtrum, Lenovo, CATT, Samsung, DCM, ZTE, Nokia, FUTUREWEI, Nordic, Ericsson, IDCC, Intel | Yes: 3  No: 17 |
| 4 | P4 | Samsung | Xiaomi, Vivo, LG, Lenovo, CATT, DCM, Nokia, FUTUREWEI, Nordic, Ericsson, IDCC | Yes: 1  No: 11 |
| 5 | P5 |  | Xiaomi, Vivo, LG, Lenovo, CATT, DCM, Nokia, FUTUREWEI, Nordic, Ericsson, IDCC |  |

Based on the 1st round email discussion, clearly P1/P3/P4/P5 was not supported by major companies and hence no proposal was made for them. On the other hand, it seems reasonable to collect companies views on P2, i.e., support of DCI 2\_x and DCI 3\_x for Redcap as the focus on the 2nd round

**FL2 High Priority Questions:**

* **Q 3-3: What’s your view on support of DCI 2-x and DCI 3-x for Redcap UEs? Please provide a motivation/justification for your answer**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | RedCap UEs can optionally support DCI format 2-x.  Regading DCI 3-x, it might be more appropriate for the V2X/SL group to decide. |
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# Other aspects

**Coverage refinement [12]**

In [12], the following was proposed for RRC\_IDLE/RRC\_INACTIVE Redcap Ues:

* **P4-1: To refine coverage recovery of RedCap UE in idle/inactive state, SS-RSRP measurements can be compressed and reported in msg3 (or msgA payload, if 2-step RACH is supported).**

**Discussion #1**

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

* + **Should we agree P4-1? Please provide a motivation for your answer.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | RAN2 issue |
| Xiaomi | N | In the coverage enhancement project, Ues can select different PRACH resource based on different channel status. In that sense, the coverage recovery request can be signalled via the selection of Msg.1. So, there is no need to indicate the channel status in Msg.3. |
| vivo | N | Coverage recovery features specific to Redcap Ues are not required by the WID. P4-1 can be considered in the coverage enhancement WI as an generic coverage enhancement solution. |
| CMCC | N | This an further enhancement since the downlink coverage can be improved by solutions available to non-RedCap Ues in NR R15/16, so it is low priority. |
| Panasonic | N | Msg3/Msg A are already well optimized. No need to have the optimization for Msg3/MsgA. |
| OPPO | N | Coverage recovery was identified not a critical issue for this WID. Coverage enhancement for non-RedCap UE in Rel-17 can be used for RedCap UE, if supported. |
| LG | N | If needed, P4-1 can be discussed under the coverage enhancement WI. |
| QC |  | Open to discuss it further |
| Lenovo, Motorola Mobility | N | As concluded, downlink coverage recovery is not an issue. |
| CATT | N | Already proven that DL coverage is not an issue in most cases. And seems out of scope anyway. |
| Samsung |  | We are open to discuss whether or not to report of CSI information in msg3 for coverage recovery, especially the one can reflect DL interference. For example, as NB-IoT/eMTC, PDCCH AL/Rep level is reported to gNB in Msg 3 for proper UE special configuration. Further the details can be FFS. |
| DOCOMO | N | This is out of WID scope |
| ZTE, Sanechips | N | It is not in the WID scope. |
| Nokia, NSB | N | There is no need for such measurement report given that downlink coverage is not an issue. |
| FUTUREWEI |  | Open for discussion. The network can use this information to improve the performance of Msg4 and beyond. |
| Ericsson | N | This feature should not be considered in Rel-17 due to the required effort to introduce the solution. |
| IDCC | N |  |
| Intel | N | As commented by others above, DL coverage is not a serious issue for RedCap. It is worse than that for non-RedCap, but nothing special beyond the degradation due to reduced BW and # of Rx branches, which is being addressed already via support of early identification. |
| China Telecom | N | We have the same understanding that it is out of WID scope. |

Moderator Summary of Discussion #1

Based on the discussions, the proposal does not get majority support and hence there is no consensus to adopt it.

**Measurement during Random Access Procedure [11]**

In Rel-15/16, a *rsrp-ThresholdSSB* is configured for the selection of the SSB during random access procedure. In addition, a *rsrp-ThresholdSSB-SUL* is configured for the selection between the NUL carrier and the SUL carrier. A UE selects an SSB with SS-RSRP above *rsrp-ThresholdSSB* amongst the associated SSBs. Contribution [11] mentioned that The SSB thresholds in Rel-15/16 are configured assuming a legacy NR UE is required to be equipped with a minimum of 4 or 2 Rx antenna ports for respective frequency bands. However, the minimum number of Rx branches supported is 1 for Redcap UEs on frequency bands where a legacy NR UE is required to be equipped with a minimum of 4 or 2 Rx antenna ports. The antenna gain will be lost with reduced number of Rx branches. For RedCap UEs, the results of RSRP measurement on SSB will degrade compared to that of legacy NR UEs. If RedCap UEs reuse the same threshold as legacy NR UEs for SSB selection, it is possible that none of the measured SSB RSRP of RedCap UEs can satisfy the threshold. The following was suggested in [11] to facilitate the SSB selection for Redcap UEs

* **P4-2: RedCap UEs specific RSRP thresholds are configured by gNB for SSB and UL carrier selection for performing random access. [11]**

In addition, it was stated in contribution [11] that for other measurement related procedure, currently network configures measurement related thresholds for legacy UEs assuming they are equipped with a minimum of 2 or 4 Rx antenna ports for specific frequency bands. It is not feasible that RedCap UEs reuse the same threshold configured for legacy NR UEs for measurement related procedure, since RedCap UEs has lower Rx antenna gain for measurement or less number of Rx branches. Therefore, the following was additionally proposed by [11]:

* **P4-3: Measurement related thresholds are configured specifically for RedCap UEs with reduced Rx branches number [11].**

**Discussion #1**

**FL1 High Priority Question 4-2:**

* + **Should we agree P4-2 and/or P4-3? Please provide a motivation for your answer.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | RAN2 issue |
| Xiaomi | P4-2: NOT support  P4-3: Yes | For P4-2, in our understanding, RedCap will not support the SUL |
| vivo | N | The Rx branch(es) used for RSRP measurement is UE implementation. Even for non-RedCap UEs with 2 or 4 Rx branches, it is not mandated to use more than 1 Rx branches for RSRP measurement, following are copied from 38.215.   |  | | --- | | For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported SS-RSRP value shall not be lower than the corresponding SS-RSRP of any of the individual receiver branches. |   1Rx may result in some RSRP accuracy degradation compared to non-RedCap UEs (RAN4 requirement work expected), but that does not mean the RSRP measurement results by RedCap UEs are always lower. |
| CMCC |  | These can be supported if justified. |
| Panasonic | Y/N | Regardless of DL loss or UL loss, when the coverage is different from non-RedCap UE, our view is different threshold needs to be taken for RedCap UEs and coverage extension UEs. The issue is not specific to RedCap UEs but common to CE agenda in our view. |
| OPPO | Y | With reduced number of Rx branches, RedCap UE experiences poor Rx RSRP compared to non-RedCap UE with more Rx branches. It is unfair to share the same RSRP threshold for RedCap UE and non-RedCap UE. The events triggered by measurements should be based on the same assumptions on the number of Rx branches of UE in the cell. Otherwise, network cannot differentiate and optimize the behaviours of different types of UE in the cell.  It is true that RAN2 will standardize the new thresholds for RedCap UE if supported. But this issue is needed to be identified in RAN1 first. |
| LG | N | From our understanding, the RSRP measured by RedCap may be somehow affected by the reduced number of Rx branches. However, considering form factors, antenna efficiency, etc., it is not quite clear for us how to determine the thresholds properly for RedCap UEs. We could just leave this for UE implementation. |
| Qualcomm | FFS | Consult RAN4/2 as well |
| Spreadtrum |  | RAN2/4 issue |
| Lenovo, Motorola Mobility |  | The motivation is not strong, could be FFS |
| CATT | Maybe Y, only if they are optional | If the gNB would like to relax the access threshold, a RedCap specific threshold may be helpful. But if the gNB would like to maintain the same DL RSRP as a unified requirement, the original threshold can be reused.  RedCap specific thresholds may be optionally configured. If not configured, the original threshold is reused. |
| Samsung | N | It’s RAN2 issue. |
| DOCOMO | N | They can be discussed in RAN2, if necessary. |
| ZTE, Sanechips |  | Depend on RAN2/4 determination. |
| Nokia, NSB | N | This seems more RAN2/RAN4 issues. |
| FUTUREWEI | Y | These thresholds can be used to indicate whether a specific RedCap UE needs improvement for the downlink |
| Nordic | N | We also think that this is in competence of RAN2 |
| Ericsson | N | These are RAN2/RAN4 issues. |
| IDCC | N |  |
| Intel | N | These are RAN2/RAN4 issues. |
| China Telecom | Y | We think the threshold should be further checked and supported properly. |

Moderator Summary of Discussion #1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Description | Yes | No | FFS | Num. of Companies |
| 1 | P4-2/P4-3 | FUTUREWEI, CATT (Maybe), OPPO, | RAN2/RAN4 issue: Huawei, Spreadtrum, Samsung, DCM, ZTE, Nokia, Nordic, Ericsson, Intel  No relaxation is needed: LG, vivo  IDCC, Xiaomi | Lenovo, Qualcomm,  CMCC,  Panasonic | Yes: 3  No: 13  FFS: 4 |

Based on the discussions, the proposal does not get majority support and hence there is no consensus to adopt it.

In [19], it is suggested to modify the existing description of ‘maxNumberMIMO-LayersPDSCH’ in TR 38.822. In current specification, it is mandatory with capability signalling to support at least 4 MIMO layers in the bands where 4Rx is specified and at least 2 MIMO layers in FR2. However, 1 Rx and 1 MIMO layer have been agreed to be supported for Redcap. In addition, the DL MIMO layer is provided by the IE of ‘MIMO-LayersDL’ as below:

MIMO-LayersDL ::= ENUMERATED {twoLayers, fourLayers, eightLayers}

For Redcap UE, at least one additional value needs to be added i.e, one layer.

Therefore, the following was suggested in [19]

* **P4-4: For the IE of maxNumber MIMO-Layers PDSCH in TR 38.822, change the description such that it is mandatory with capability signalling to support at least 1 MIMO layer in both FR1 and FR2 for RedCap**
* **P4-5: Define separate value set for the IE of MIMO-LayersDL in TS 38.331.**

**Discussion #1**

**FL1 High Priority Question 4-3:**

* + **Should we agree P4-4 and/or P4-5? Please provide a motivation for your answer.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon | No for P 4-4  Yes for P4-5 | Candidate values (P 4-5) can be defined in RAN1 and informed to RAN2 while signalling design (P 4-4) belongs to RAN2 expertise. |
| Xiaomi |  | We are OK with uawei’s comment |
| vivo | N | We suggest to leave those questions for RAN2 to decide. |
| CMCC |  | OK with Huawei’s comment. |
| Panasonic | Y |  |
| OPPO | Y |  |
| LG |  | Agree with vivo. |
| Qualcomm | N |  |
| CATT |  | Prefer to clarify first whether we should have this discussion in RAN2, or AI 8.6.1.2 or 8.6.1.4 or even 8.6.2.  Some companies are discussing the similar issues in AI 8.6.1.4. We also point out in R1-2106980 that description of *maxNumberMIMO-LayersPDSCH* in TR 38.822 and TS 38.806 need to be updated. On the value set, at least R1-2104368 in RAN1#105-e pointed out that two different ways can be considered for reporting single layer. |
| Samsung | P4-4: Y  P4-5: N | P4-5 is not needed. The applicable values already include candidate values for RedCap Ues. |
| DOCOMO | N | They can be discussed in RAN2 |
| ZTE, Sanechips | N | RAN1 can give which higher layer parameters are affected for RedCap Ues. And whether/ how to optimize these parameters is determined by RAN2. |
| Nokia, NSB | N | We can leave to RAN2 to decide. |
| FUTUREWEI: | N | The signaling can be discussed in RAN2 |
| Nordic | N | Specs are in RAN2 scope |
| Ericsson | N | Signaling details are up to RAN2. |
| Sharp | N | How to capture the relationship between Rx and DL MIMO layer for RedCap is under RAN2’ discussion. RAN1 does not need to discuss it for now. |
| IDCC | N |  |
| Intel | N | These are RAN2 details. |
| China Telecom | N | It is up to RAN2 decision. |

Moderator Summary of Discussion #1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Description | Yes | No | Num. of Companies |
| 1 | P4-4 | Panasonic, OPPO, Samsung, | HW, Xiaomi, vivo, CMCC, LG, Qualcomm, DCM, ZTE, Nokia, FUTUREWEI, Nordic, Ericsson, Sharp, IDCC, Intel, China Telecom | Yes: 3  No: 16 |
| 2 | P4-5 | HW, Xiaomi, CMCC, Panasonic, OPPO, | Vivo, LG, Qualcomm, Samsung, DCM, ZTE, Nokia, FUTUREWEI, Nordic, Ericsson, Sharp, IDCC, Intel, China Telecom | Yes: 5  No: 14 |

Based on the discussions, the proposal does not get majority support and hence there is no consensus to adopt it.

**Early Identification of # Rx branches [21]**

Contribution [21] proposed to support early identification of Rx branches to improve the network performance. However, the following was concluded in last RAN1 105 e-meeting already for this issue and repeated discussion should be avoided to efficiently utilize the limited meeting time:

|  |
| --- |
| **Conclusion:**   * No consensus to support early identification of the number of Rx branches in Msg1/Msg3/MsgA for Redcap UE in Rel-17 |

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

* + **What’s your view to re-discuss the early identification of Rx branches number?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | Similar comment as FL |
| Xiaomi |  | No need to re-discuss it |
| vivo | N | RAN1 conclusion has been made already, no need to re-open the discussion. |
| CMCC |  | No need to re-discuss it |
| Panasonic | N | No need to discuss it again as we expect the same conclusion. |
| OPPO |  | We can focus on the early identification of RedCap UE type. |
| LG | N |  |
| Qualcomm | N | No need to open the discussion again |
| CATT |  | We do not see the need of re-discussion. |
| Samsung | N | No need to discuss again. |
| DOCOMO | N |  |
| ZTE, Sanechips |  | No need to revisit. |
| Nokia, NSB |  | No need to discuss again. |
| Nordic | N |  |
| Ericsson | N |  |
| Sharp | N |  |
| IDCC | N | No need for discussion. |
| Intel | N |  |
| China Telecom | N |  |

# Annex: Companies’ point of contact

**FL1 Question: Please consider entering contact info below for the points of contact for this email discussion.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Point of contact** | **Email address** |
| vivo | Xueming Pan | panxueming@vivo.com |
| Spreadtrum communications | Sicong Zhao | Sicong.zhao@unisoc.com |
| CATT | Yongqiang FEI | feiyongqiang@catt.cn |
| DOCOMO | Shinya Kumagai | shinya.kumagai@docomo-lab.com |
| ZTE, Sanechips | Youjun Hu | hu.youjun1@zte.com.cn |
| Nokia, NSB | Rapeepat Ratasuk | rapeepat.ratasuk@nokia-bell-labs.com |
| FUTUREWEI | Vip Desai | vipul.desai@futurewei.com |
| Nordic | Karol Schober | karol.schober@nordicsemi.no |
| Ericsson | Sandeep Narayanan Kadan Veedu | sandeep.narayanan.kadan.veedu@ericsson.com |
| Intel | Debdeep Chatterjee | debdeep.chatterjee@intel.com |
| China Telecom | Jing Guo | guojing6@chinatelecom.cn |
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# References

1. RP-211574 Revised WID on support of reduced capability NR devices Ericsson
2. R1-2106213 RAN1 agreements for Rel-17 NR RedCap Rapporteur (Ericsson)
3. [R1-2106460](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106460.zip) Reduced number of Rx branches for RedCap Huawei, HiSilicon
4. [R1-2106564](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106564.zip) Reduced number of Rx branches for RedCap Ericsson
5. [R1-2106602](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106602.zip) Discussion on reduced number of Rx branches vivo, Guangdong Genius
6. [R1-2106649](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106649.zip) UE Complexity Reduction aspects related to reduced number of Rx branches Nokia, Nokia Shanghai Bell
7. [R1-2106842](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106842.zip) Discussion on reduced number of UE Rx branches ZTE, Sanechips
8. [R1-2106895](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106895.zip) Discussion on reduced number of RX branches for RedCap UEs Samsung
9. [R1-2106978](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2106978.zip) Discussion on reduced number of Rx branches CATT
10. [R1-2107041](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107041.zip) On aspects related to reduced number of Rx branches Nordic Semiconductor ASA
11. [R1-2107250](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107250.zip) Discussion on reduced number of UE Rx branches OPPO
12. [R1-2107352](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107352.zip) RX Branch Reduction for RedCap UE Qualcomm Incorporated
13. [R1-2107409](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107409.zip) Discussion on aspects related to reduced number of Rx branches CMCC
14. [R1-2107449](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107449.zip) Aspects related to the reduced number of Rx branches of RedCap LG Electronics
15. [R1-2107746](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107746.zip) On reduced number of Rx branches for Redcap Apple
16. [R1-2107795](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107795.zip) Discussion on reduced minimum number of Rx branches Sharp
17. [R1-2107810](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107810.zip) Reduced number of Rx branches for RedCap UEs InterDigital, Inc.
18. [R1-2107865](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107865.zip) Discussion on reduced minimum number of Rx branches for RedCap NTT DOCOMO, INC.
19. [R1-2107927](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107927.zip) Discussion on the remaining issues of reduced Rx for RedCap Xiaomi
20. [R1-2107948](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2107948.zip) Remain issues for reduced number or Rx branches for RedCap Lenovo, Motorola Mobility
21. [R1-2108098](file:///D:\Documents\3GPP%20documents\RAN1\TSGR1_106-e\Docs\R1-2108098.zip) Discussion on reduced number of Rx branches China Unicom