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:

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| [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
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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 ‘FL1’ before Monday 16th 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.

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|  | 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.
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| 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]
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| 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.
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| 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.
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**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: YesQ2-2: Alt 3/4/5/6/7 | …. |
| Huawei, HiSilicon | Y for Q 2-1No 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. |
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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.
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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]:

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| **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.
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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:

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| 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).
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| P4 [8] | * Support reduction of MCS field for non\_fallback DCI format for RedCap UEs by 1 or 2 bits with configurable entries.
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| 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.
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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 potenital 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.

**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: YesQ 3-2: P1, P3, P4 | …. |
| Huawei, HiSilicon | Q 3-1: unclearQ 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. |
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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).**

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

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

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | RAN2 issue |
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**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].**

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

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

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | RAN2 issue |
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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.**

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

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

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon | No for P 4-4Yes 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.  |
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**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:

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| **Conclusion:*** No consensus to support early identification of the number of Rx branches in Msg1/Msg3/MsgA for Redcap UE in Rel-17
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**FL1 High Priority Question 4-4:**

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

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSilicon |  | Similar comment as FL |
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# Annex: Companies’ point of contact

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

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| **Company** | **Point of contact** | **Email address** |
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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%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106460.zip) Reduced number of Rx branches for RedCap Huawei, HiSilicon
4. [R1-2106564](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106564.zip) Reduced number of Rx branches for RedCap Ericsson
5. [R1-2106602](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106602.zip) Discussion on reduced number of Rx branches vivo, Guangdong Genius
6. [R1-2106649](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106649.zip) UE Complexity Reduction aspects related to reduced number of Rx branches Nokia, Nokia Shanghai Bell
7. [R1-2106842](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106842.zip) Discussion on reduced number of UE Rx branches ZTE, Sanechips
8. [R1-2106895](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106895.zip) Discussion on reduced number of RX branches for RedCap UEs Samsung
9. [R1-2106978](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106978.zip) Discussion on reduced number of Rx branches CATT
10. [R1-2107041](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107041.zip) On aspects related to reduced number of Rx branches Nordic Semiconductor ASA
11. [R1-2107250](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107250.zip) Discussion on reduced number of UE Rx branches OPPO
12. [R1-2107352](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107352.zip) RX Branch Reduction for RedCap UE Qualcomm Incorporated
13. [R1-2107409](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107409.zip) Discussion on aspects related to reduced number of Rx branches CMCC
14. [R1-2107449](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107449.zip) Aspects related to the reduced number of Rx branches of RedCap LG Electronics
15. [R1-2107746](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107746.zip) On reduced number of Rx branches for Redcap Apple
16. [R1-2107795](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107795.zip) Discussion on reduced minimum number of Rx branches Sharp
17. [R1-2107810](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107810.zip) Reduced number of Rx branches for RedCap UEs InterDigital, Inc.
18. [R1-2107865](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107865.zip) Discussion on reduced minimum number of Rx branches for RedCap NTT DOCOMO, INC.
19. [R1-2107927](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107927.zip) Discussion on the remaining issues of reduced Rx for RedCap Xiaomi
20. [R1-2107948](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107948.zip) Remain issues for reduced number or Rx branches for RedCap Lenovo, Motorola Mobility
21. [R1-2108098](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2108098.zip) Discussion on reduced number of Rx branches China Unicom