

3GPP TSG-RAN WG1 Meeting #105-e R1-2106333

e-Meeting, May 10<sup>th</sup> – 27<sup>th</sup>, 2021

Agenda Item: 8.6.1.2

Title: FL summary #4 for reduced number of Rx branches for RedCap

Source: Moderator (Apple)

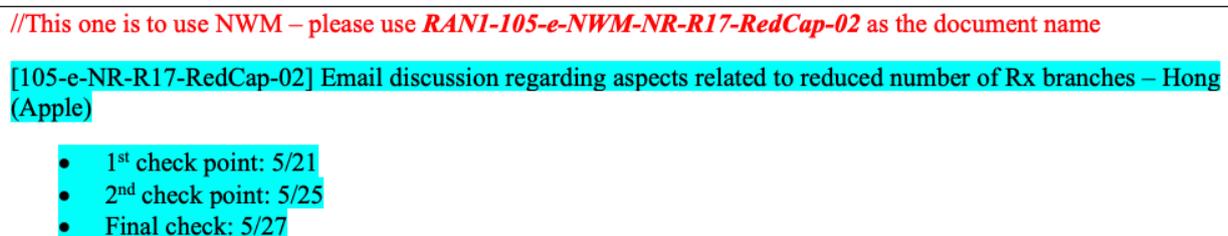
Document for: Discussion, Decision

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## 1 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.



//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)

- 1<sup>st</sup> check point: 5/21
- 2<sup>nd</sup> check point: 5/25
- Final check: 5/27

**Figure 1:**

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

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]:

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].**

- 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).

**Figure 2:**

- 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)

**Figure 3:**

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## 2 Reporting of Number of Rx branches

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

**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

**Figure 4:**

## 2.1 Earlier Indication of the Number of Rx branches (Closed)

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:

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 Conclusion 2-1:**

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

**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],	<ul style="list-style-type: none"> <li>• Avoid conservative scheduling for Msg2/Msg4 and mitigate latency degradation for 1-Rx device [4][8][11] [12].</li> <li>• Flexible and Fine-grained cell access control [8][9]</li> <li>• Reduce PDCCH blocking during initial access [11]</li> <li>• Apply DL coverage recovery for 1-Rx Redcap device [18] [32]</li> </ul>	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]	<ul style="list-style-type: none"> <li>• 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].</li> </ul> <p><b>On DL coverage compensation motivation:</b></p> <ul style="list-style-type: none"> <li>• No DL coverage enhancement was agreed for Redcap with 1-Rx branch [6][7][14][22][29].</li> <li>• For RedCap UE with 1Rx, it does not always mean its channel condition is poor [6][14][26].</li> <li>• The DL coverage gap between 1-Rx and 2-Rx for Redcap is smaller compared to that between Redcap and non-Redcap UEs [5].</li> <li>• 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 for all RedCap UEs regardless of the number of UE's Rx branches [3][5][6][14][16].</li> </ul> <p>Others:</p> <ul style="list-style-type: none"> <li>• 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].</li> <li>• 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].</li> <li>• Avoid the unnecessary specification work [3]</li> </ul>	14

**Figure 5:**

2.1.1 <1st Round Comments>

**Feedback Form 1: Can we agree the above conclusion 2-1? If not, please clarify the justification:**

**1 – QUALCOMM JAPAN LLC.**

We are ok with this conclusion.

Besides, when the initial UL BWP of non-RedCap UE is wider than the max BW of RedCap UE, we think early indication should be supported for the identification of BW reduction, which is the most pronounced UE feature for R17 RedCap devices.

**2 – vivo Communication Technology**

[vivo] OK with the conclusion

**3 – Nordic Semiconductor ASA**

We are OK. the aspect of Rx branches can be included still in early identification of UEs based on RSRP and/or need for MSG3 repetitions.

**4 – NEC Corporation**

We are OK with the conclusion.

**5 – Spreadtrum Communications**

We are fine with this conclusion.

**6 – CATT**

OK with the conclusion.

**7 – ZTE Corporation**

[ZTE]We propose to define earlier identification of number of Rx branches as an optional capability because the early identification in Msg1/Msg3 can help avoid conservative scheduling, reduce PDCCH blocking and achieve flexible access control. In some scenarios, earlier identification of number of Rx branches can be enabled to improve performance. For example, earlier identification in Msg1 can be used when the uplink resources are sufficient.

Moreover, the access control of RedCap UEs via Msg4 is now considered by RAN2, so earlier identification of number of Rx branches should not be excluded prematurely by RAN1.

**8 – Nokia**

We believe early identification of number of Rx branches would be useful for the reasons listed in the FL summary. We feel that is separate UL BWP and separate PRACH resources are configured for RedCap UE, there would be no issue on PRACH resource to support identification of number of Rx branches. Therefore, we feel this should be supported as an optional feature.

<p><b>9 – Chengdu OPPO Mobile Com. corp.</b></p> <p>[OPPO] We prefer to support earlier indication as an optional feature. With earlier identification of RedCap UE with reduced number of Rx branches, gNB can have the opportunity to improve performance with right scheduling, reduce PDCCH blocking and so on. It can be configurable in system information based on, e.g. PRACH resource load.</p>
<p><b>10 – Samsung Research America</b></p> <p>[Samsung] We are fine with the conclusion.</p>
<p><b>11 – Futurewei Technologies</b></p> <p>[FUTUREWEI] Early identification is useful as captured in the summary, especially to address the resulting performance degradation due to a reduced number of Rx branches. We feel that early identification should be supported as a configurable in system information.</p>
<p><b>12 – Ericsson LM</b></p> <p>[Ericsson] Yes</p>
<p><b>13 – Intel Corporation (UK) Ltd</b></p> <p>[Intel] Support the conclusion.</p>
<p><b>14 – SHARP Corporation</b></p> <p>[Sharp] We are fine with the conclusion.</p>
<p><b>15 – Panasonic Corporation</b></p> <p>[Panasonic] support the conclusion.</p>
<p><b>16 – LG Electronics Inc.</b></p> <p>[LG] We are okay with the conclusion.</p> <p>Although not explicitly stated in our contribution, we are also negative to support earlier identification of number of Rx branches in Msg1/Msg3/MsgA. We concern the PRACH portioning for Msg1 early identification and are not sure of the benefit of early identification of the number of Rx branches in Msg3.</p>
<p><b>17 – Beijing Xiaomi Mobile Software</b></p> <p>[Xiaomi] We are fine with the conclusion.</p>
<p><b>18 – HUAWEI Technologies Japan K.K.</b></p> <p>[Huawei, HiSi]Ok</p>
<p><b>19 – NTT DOCOMO INC.</b></p> <p>[DOCOMO] We are fine with the conclusion</p>

<p><b>20 – China Telecommunications</b></p> <p>[China Telecom] We are fine with this conclusion.</p>
<p><b>21 – China Mobile Com. Corporation</b></p> <p>[CMCC] Early indication of # Rx branches can be optionally supported to improve spectrum efficiency.</p>
<p><b>22 – Lenovo (Beijing) Ltd</b></p> <p>[Lenovo, Motorola Mobility] We also think early indication of number of Rx branches could be optionally configured e.g., for the case that separate initial UL BWP and ROs are configured for RedCap UEs.</p>
<p><b>23 – Fraunhofer HHI</b></p> <p>We see a clear benefit of early identification of the number of Rx branches. Especially, PDCCH blocking issues and a wasted sepctral efficiency can be easily adressed by the early indication.</p>
<p><b>24 – Sierra Wireless</b></p> <p>Not supportive of this conclusion. The number of RX Ants (e.g. 1 vs 2) clearly impacts initial access more than any other RedCap attribute (e.g. HD-FDD, 20MHz BW, 64QAM DL) so missing this indication will have the greatest effect on system performance. The main argument made to not support # of RX Ant in Msg1, is that this will increase the number of PRACH partitions needed but this is not necessary true as it will depend on the design of the early indication mechanism from AI 8.6.2. In most case, only one addition PRACH partition is needed; 1 RX RedCap UEs will use the additional PRACH partition and 2 or 4 RX RedCap UEs can use the normal PRACH partition. As explained, there is a clear linkage between this and the design of early identification mechanism which is done in AI 8.6.2 so more progress needs to be done on the design of early identification mechanism before this conclusion can be made.</p>
<p><b>25 – Sony Europe B.V.</b></p> <p>It is reasonably clear that there is no consensus at this stage, given the comments above. Our view is that it would be helpful for the network to know via early indication whether the UE has 1 RX antenna (or, more to the point, whether the UE has impaired DL performance, whether due to having 1RX antenna or two small form factor antennas etc.)</p>

2.1.2 <1st Round Summary>

**Table 1: Summary of Companies responses for 'Conclusion 2-1'**

	Companies	# Companies
Yes	Qualcomm, vivo, Nordic, NEC, Spreadtrum, CATT, Samsung, Ericsson, Intel, Sharp, Panasonic, LG, Xiaomi, Huawei, DoCoMo, China Telecom	16
No	ZTE, Nokia, OPPO, Futurewei, CMCC, Lenovo, Fraunhofer HHI	7

2.1.3 <2nd Round Comments>

[FL3] High Priority Question 2-1:

**Based on the discussion of the 1st round and further explanations from proponents, can we agree to introduce the earlier indication of Redcap UEs with # Rx branches by Msg1 and/or Msg3, and MsgA, that is configurable by gNB? If NOT, please explain the critical concern(s).**

**Feedback Form 2: Based on the discussion of the 1st round and explanations from proponents, can we agree to introduce the earlier indication of Redcap UEs with Rx branches by Msg1 and/or Msg3, and MsgA, that is configurable by gNB? If NOT, please explain the critical concern(s).**

<p><b>1 – vivo Communication Technology</b></p> <p>[vivo] No. We think the previous version of FL conclusion, i.e. no consensus on this topic, represents the situation pretty well.</p>
<p><b>2 – Panasonic Corporation</b></p> <p>[Panasonic] No, we don't support. We don't see a large gain by avoiding conservative scheduling for 2Rx UEs only for Msg2/4, while Msg1 partitioning and/or Msg3 overhead is needed.</p>
<p><b>3 – CATT</b></p> <p>[CATT] No. Prefer not to have any kind of early indication of Rx# during the initial access, considering the marginal gain but significant spec impact.</p>
<p><b>4 – China Mobile Com. Corporation</b></p> <p>[CMCC] Yes. Whether by Msg.1 or Msg3 can depend on outcome from 8.6.1.1</p>
<p><b>5 – Nordic Semiconductor ASA</b></p> <p>As said before, in addition to RedCap UE identification , it would be beneficial to early identify need for CovEnh. If that is supported, then no need for explicit Rx antenna early identification as such.</p>
<p><b>6 – NEC Corporation</b></p> <p>[NEC] No. We don't see much motivation from RAN1 perspective.</p>
<p><b>7 – HUAWEI Technologies Japan K.K.</b></p> <p>[Huawei, HiSi] Ok with previous version. However, if there is large gain can be observed and agreed to the group, we can consider to include it for early identification, conditioned that it is not assumed that a specific Rx number is mandatory supported, according to the discussion in UE type definition.</p>
<p><b>8 – Spreadtrum Communications</b></p> <p>[Spreadtrum] No. First, we don't have consensus on the benefit of earlier indication of Rx branches. Second, the early identification of RedCap UEs (e.g., in Msg1) is configurable, it means the information of the UE type is not that critical, then the information of Rx branches may not that important.</p>

Therefore, we prefer to have the previous conclusion that there is no consensus to support earlier identification of number of Rx branches.

#### **9 – LG Electronics Inc.**

[LG] We prefer the previous version of FL conclusion as we think it reflects the situation better. As commented before, we are still concerned about the partitioning of PRACH resources and also not sure about the benefit of earlier indication of the number of Rx branches in Msg3. Furthermore, as we don't expect significant performance differences between 1Rx and 2Rx RedCap UEs, we believe that early indication for distinguishing RedCap/non-RedCap UEs in Msg1 is sufficient.

#### **10 – ZTE Corporation**

[ZTE] Yes.

The earlier indication of # Rx branches show the advantages including avoiding conservative scheduling, providing flexible access control, lower PDCCH blocking, applying coverage compensation, which are summarized by the FL. The earlier indication of # Rx branches should not be precluded at least.

Additionally, it is worth mentioning that the earlier indication of # Rx branches can bring more efficient network scheduling, and also help UE and gNB save more power consumption brought by redundant repetition and power boosting. Therefore, even it is optionally indicated, a large amount of benefits can be observed. As for the Msg1 partitioning and/or Msg3 overhead, this issue can be avoided by the gNB scheduling. The gNB can configure the earlier indication of # Rx branches, when the current network capacity indicates the PRACH resources are sufficient.

#### **11 – Nokia**

[Nokia] Yes. It is beneficial to have early identification of the number of Rx branches. As discussed in our previous response, the impact on PRACH can be a consideration in deciding whether to enable this or not. But we support the ability for gNB to be able to configure early identification of the number of Rx branches.

#### **12 – NTT DOCOMO INC.**

[DOCOMO] No. We don't see clear benefit to introduce the indication while overhead of PRACH resource is not negligible.

#### **13 – Futurewei Technologies**

[FUTUREWEI] Yes. There is no critical problem with allowing the possibility of RX branches by configuration (or not). The motivation should be clear from RAN discussion, where early identification was included as part of the discussion to allow 1RX. If an operator does not see the benefit then they won't configure it.

Note: We have to be very careful on the conclusions here, as we still need to discuss e.g. RSRP thresholds for ROs which may be configurable and may identify a UE as "RedCap".

#### **14 – Samsung Research America**

[Samsung]: No. We are not convinced by the benefits of early indication. Regarding DL coverage recovery for 1Rx device, as the RAR addresses multiple UEs, there is little for the gNB to gain if the number of Rx antennas is known by Msg1. Only benefit for indicating by Msg1 will be when all UEs addressed by RAR have 2 Rx (not worth it), otherwise gNB may need to assume the worst case. For Msg3 related to flexible

cell access control, we think it should not make much difference at that point if UE blocking happens after the UE declares the capability. So, we think it's not worth the trouble to consider early indication of rx branches based on Msg1 and/or Msg3.

#### **15 – Chengdu OPPO Mobile Com. corp.**

[OPPO] Yes. Some companies have clarified the benefits of earlier indication during the 1st round comments. If the earlier indication can be configurable, vendor and operator can enable/disable the earlier indication based on the network situation, e.g. the amount of RedCap UEs in the cell and PRACH resources overhead. We prefer to support the earlier indication configurable.

#### **16 – Ericsson LM**

[Ericsson] No. Although we appreciate the clarifications from the proponents, it is still our view that the incentive for early indication of number of Rx branches in Msg1 is minimal compared to its drawbacks.

However, we are open to the consideration of early indication of number of Rx branches in Msg3 (e.g., using a separate LCID), as this solution is not associated with the PRACH fragmentation issue of Msg1 indication.

#### **17 – Sierra Wireless**

[Sierra Wireless] Yes - Support. A one size fits all approach is not a good idea here as there are many factors and system configurations (e.g. inter-site distance, band, TDD/FDD, etc.) which can affect whether a system can benefit from knowing 1 RX or 2 RX. Also, given that future changes to initial access procedures are impossible, making sure the initial access designed is as flexibly as possible is judicious. Also given the complexities in NR already, this configurability would rank very low on the "too much trouble" scale. Since RAN2 will design this configurability and best knows how much "trouble" it will be, we should leave complexity discussions up to them where RAN1 could make a conclusion stating that under what conditions there is value in a design where Msg1 is configured to indicate the number of antennas.

#### **18 – QUALCOMM JAPAN LLC.**

[Qualcomm] We don't see a strong motivation to support early indication of RX branch number in msg1 or msgA.

#### **19 – Intel Corporation (UK) Ltd**

[Intel] No, we have not seen sufficient justification for early indication of #of Rx branches to justify early identification, which is rather expensive in terms of PRACH capacity and/or OH.

In the absence of such indication, a RedCap UE will be identified as a 1Rx when it may actually have 2Rx, and this impacts PDCCH/PDSCH of Msg2/Msg4.

The overall impact from any potential sub-optimality in selection of PDCCH ALs or MCS, TB scaling, etc. for PDSCH would be negligible unless we have a large number of RedCap UEs with 2Rx relative to RedCap UEs with 1Rx or non-RedCap UEs in the cell.

As of now, we do not think that we are expecting and designing for such scenarios.

#### **20 – SHARP Corporation**

[Sharp] No. Previous FL conclusion is our preference. As mentioned by other companies, 1 Rx RedCap UEs are not always in poor channel condition than 2 Rx RedCap UEs. Early indication of number of

branches would trigger further potential impact discussion on ,e.g., whether to seperate RA search space, or seperate Msg2/Msg4.

**21 – Beijing Xiaomi Mobile Software**

[Xiaomi] We think the previous version proposal is better and it may not be urgent to conclude this issue in this meeting.

2.1.4 <2nd Round Summary>

Table 2 below summarizes the responses from companies on earlier indication of # Rx branches:

**Table 2: Summary of Companies Positions for Question 2-1.**

	Companies	# of Companies
Yes	CMCC, ZTE, Nokia, Futurewei, OPPO, Sierra Wireless	6
No	vivo, Panasonic, CATT, NEC, Huawei(ok with previous version), Spreadtrum, LGe, DoCoMo, Samsung, Ericsson, Qualcomm, Intel, Sharp, Xiaomi	14
Others	Nordic (depending on whether earlier identification for CovEnh is introduced or not)	1

**[FL4] High Priority Proposal 2-1: Select one of following alternatives:**

- **Alt.1: Conclusion that 'No consensus to support earlier identification of number of Rx branches in Msg1/Msg3/MsgA for Redcap UE'.**

-**Alt.2: Support the earlier indication of # Rx branches for RedCap UEs by Msg1 and/or Msg3, and MsgA, which is configurable by gNB in SIB1**

The following was agreed in Tuesday GTW Session:

**Conclusion**

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

**Figure 6:**

2.2 Number of Rx Branches Report in UE capability (Closed)

The following was agreed in Friday GTW session:

**Agreement:**

For UE capability signalling, the number of Rx branches for RedCap is implicitly indicated by the corresponding capability parameter *maxNumberMIMO-LayersPDSCH* in the existing UE capability framework.

- Detailed signalling is up to RAN2

**Figure 7:**

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## 3 DCI formats for Redcap

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

**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.

**Figure 8:**

The following was agreed in Friday GTW session

**Agreement:**

- Redcap UE is mandated to support at least DCI format 0\_0/1\_0.

**Figure 9:**

### 3.1 Existing DCI formats Support for Redcap (Closed)

On the DCI format support for Redcap UEs (i.e., 2<sup>nd</sup> FFS), the views are categorized in Table 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].

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

#	DCI formats (M: Mandatory; O: Optional)			Companies	Reasoning	# Compa nies
	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]	<ul style="list-style-type: none"> <li>• Same as legacy [3][5].</li> <li>• 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].</li> </ul>	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]	<ul style="list-style-type: none"> <li>• DCI x_2 can further reduce PDCCH overhead [16][20].</li> <li>• gNB can configure DCI format x_2 to be same as DCI format x_1 if needed [16][20].</li> </ul>	3

**Figure 10:**

3.1.1 <1st Round Comments>

**[FL1] High Priority Question 3-1**

**Regarding DCI format 0\_1/1\_1 and DCI format 0\_2 and 1\_2, three options can be considered.**

**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.**

**Feedback Form 3: Which option above should be adopted for Redcap? Please provide brief justification for your preference.**

**1 – QUALCOMM JAPAN LLC.**

We prefer Option 3. Option 1 is not necessary for RedCap UE, since it is not helpful to align/reduce the size of different DCI formats.

<p><b>2 – vivo Communication Technology</b></p> <p>[vivo] Option 2. DCI 0_2/1_2 are optional for non-redcap UEs, we prefer to keep the same assumption for redcap UEs.</p>
<p><b>3 – Nordic Semiconductor ASA</b></p> <p>We are open to Option 2/3. We are not OK with Option 1.</p>
<p><b>4 – NEC Corporation</b></p> <p>Our preference is same as legacy UE, i.e. option2.</p>
<p><b>5 – Spreadtrum Communications</b></p> <p>we prefer option 3, DCI x_2 can further reduce PDCCH overhead</p>
<p><b>6 – CATT</b></p> <p>Either Option 2 or Option 3 is fine. Not support Option 1.</p>
<p><b>7 – ZTE Corporation</b></p> <p>We recommend that both are optional based on use case requirements.</p>
<p><b>8 – Nokia</b></p> <p>We prefer Option 3</p>
<p><b>9 – Chengdu OPPO Mobile Com. corp.</b></p> <p>[OPPO] Option2, as defined for legacy non RedCap UE.</p>
<p><b>10 – Samsung Research America</b></p> <p>[Samsung] We prefer option 3.</p> <p>Only one type of non-fallback DCI formats are needed.</p> <p>DCI formats x_2 has higher flexibility than DCI format x_1 regarding the DCI payload size to support. Smaller DCI payload size is beneficial for RedCap UEs.</p> <p>Also, DCI format x_2 can be configured same as DCI formats x_1 except those fields related to TB2 and CBG, which are not needed for RedCap UEs with small TBS.</p>
<p><b>11 – Futurewei Technologies</b></p> <p>[FUTUREWEI] Option 1 or 3. We would like to ensure the compact DCI is available to address the performance degradation due to the reduced number of Rx branches</p>
<p><b>12 – Ericsson LM</b></p> <p>[Ericsson] Option 2.</p> <p>The FFS on which DCI formats are mandatory for the RedCap UEs was in the context of reducing PDCCH blocking. In this context, we do not see a need to make DCI 02/12 mandatory. The reasons are as follows:</p>

-  
Our simulation results show that for a typical range of simultaneously scheduled UEs, the impact on PDCCH blocking due to reducing the number of Rx branches is small. In addition, reducing the DCI size will also have a minimal impact on PDCCH blocking in this range. Even if the number of scheduled UEs are high, the DCI size must be reduced by half (or more) to have any meaningful reduction in PDCCH blocking. This is unlikely for RedCap.

-  
Even if DCI 02/12 is mandatory, it can be used for scheduling only in RRC\_CONNECTED state. In this state, if needed, there is already possibility for the gNB to configure additional BWP/CORESET to reduce PDCCH blocking. Also, if needed, the gNB can prioritize scheduling of legacy UEs over RedCap UEs, which can also help to reduce the PDCCH blocking.

**13 – Intel Corporation (UK) Ltd**

[Intel] Option 2 is slightly preferred considering the benefits from Option 3 are limited (as pointed out, e.g., by Ericsson), and the fact that Option 2 implies less spec impact and less demands on the gNB side (e.g., a gNB may currently only support 0\_1/1\_1 and not 0\_2/1\_2).

**14 – SHARP Corporation**

[Sharp] Option 3 is preferred. Agree with Samsung.

**15 – Panasonic Corporation**

[Panasonic] Support the Option 3. As DCI format 0\_2/1\_2 are super set function of DCI 0\_1/1\_1 and it is used for UE specific operation, to mandate DCI format 0\_2/1\_2 is sufficient.

**16 – LG Electronics Inc.**

[LG] We support option 3. No modification from the non-RedCap is needed.

**17 – HUAWEI Technologies Japan K.K.**

[Huawei, HiSi] option2

**18 – NTT DOCOMO INC.**

[DOCOMO] Option 2 as non-RedCap UEs

**19 – China Telecommunications**

[China Telecom] We support Option 2 and Option 3. And Option 3 is preferred.

**20 – China Mobile Com. Corporation**

[CMCC] We are OK for both option 2 and option 3.

**21 – Xiaomi Communications**

[Xiaomi] We prefer opt.2

<p><b>22 – Lenovo (Beijing) Ltd</b></p> <p>[Lenovo, Motorola Mobility] We prefer option 2.</p>
<p><b>23 – Fraunhofer HHI</b></p> <p>We prefer Option 3. Option 1 is unnecessary for RedCap UEs and compared to Option 2, Option 3 offers higher flexibility and thus a reduced PDCCH payload.</p>
<p><b>24 – LG Electronics Inc.</b></p> <p>[LG] We prefer Option 2.</p> <p>Sorry for the earlier comment. There was a slight mistake when writing it.</p>
<p><b>25 – Sony Europe B.V.</b></p> <p>prefer option 2</p>

### 3.1.2 <1st Round Summary>

**Table 3: Summary of responses on non-fallback DCI Formats**

	Companies	# of Companies
Opt.1	Futurewei	1
Opt.2	Vivo, Nordic, NEC, CATT, OPPO, Ericsson, Intel (Slightly preferred), Huawei, DoCoMo, China Telecom, CMCC, Xiaomi, Lenovo, LGe	14
Opt.3	Qualcomm, Nordic, Spreadtrum, CATT, Nokia, Samsung, Futurewei, Sharp, Panasonic, China Telecom (preferred), CMCC, Fraunhofer HHI	12
Others	ZTE: Both optional	1

### 3.1.3 <2nd Round Comments>

Clearly, Opt.2 and Opt.3 got majority supports. To facilitate the potential down-selection, companies are asked to provide views on Opt.2 vs. Opt.3 from the following perspectives?

- Which Option is NOT accepted? Please provide brief justification.

- There is one interesting point raised by one company, i.e., Intel, regarding DCI Format x\_2 optionally supported by legacy UE and more importantly by legacy gNB. Consequently, mandating x\_2 for Redcap UE may either cause more burden for gNB if it wants to operate Redcap in system. Please share your views on

this regard as well.

**[FL3] High Priority Question 3-3:**

**Which one of 'Opt.2 and Opt.3' is NOT acceptable? Please provide brief justification. Also provide views on interesting point raised by one company (i.e., Intel) in the 1st round as explained above.**

**Feedback Form 4: Which one( Opt.2 vs. Opt.3) is NOT acceptable? Please provide brief justification. Also provide views on interesting point raised by one company (Intel) in the 1st round as explained above.**

<p><b>1 – vivo Communication Technology</b></p> <p>[vivo] We still prefer Option 2 and would not accept option 3. We would like to keep the design principle consistent, i.e. optional features for non-redcap UEs will be optional for redcap UEs by default. And we do agree with Intel's point.</p>
<p><b>2 – China Mobile Com. Corporation</b></p> <p>[CMCC] Considering the traditional gNB may not support x_2, option 2 is slightly preferred.</p>
<p><b>3 – CATT</b></p> <p>[CATT] Our initial thinking is either Option 2 or Option 3 is fine. But Intel's concern that Option 3 will force gNB to support DCI format x_2 (which may not be largely implemented yet) is reasonable. We now slightly prefer Option 2 to ease the RedCap deployment to gNB.</p>
<p><b>4 – Nordic Semiconductor ASA</b></p> <p>We do not have strong view here. Regarding, the point raised by Intel, we had the similar observation as ///, that saving few bits does not make any miracles in the end, while all the eMBB UEs support 1_1 and 0_1, therefore Option 2 is baseline according to WID spirit, which says that eMBB UE capabilities are starting point for RedCap. So unless we have consensus for Option 3, option 2 is what we have.</p>
<p><b>5 – NEC Corporation</b></p> <p>[NEC] Our preference is option 2. We are in general not in favor of mandating optional features for non-RedCap UE.</p>
<p><b>6 – HUAWEI Technologies Japan K.K.</b></p> <p>[Huawei, HiSi] Option2 is more mature from both gNB and UE point of view.</p>
<p><b>7 – Panasonic Corporation</b></p> <p>[Panasonic]</p> <p>We don't support Opt.2. RedCap UEs should support DCI 0_2/1_2 to mitigate PDCCH blocking. For those UEs, supporting 0_1/1_1 is redundant as 0_1/1_1 functionality is covered by 0_2/1_2.</p> <p>Regarding Intel's comment: for RedCap deployment, the gNB is in any way required to support some modification related to the bandwidth. Compared with these modification, our view is to support DCI 0_2/1_2 (which is Rel-16 function) is less modification to gNB. Therefore, we don't share the concern.</p>

## **8 – Spreadtrum Communications**

[Spreadtrum] We think both 'Opt.2 and Opt.3' are acceptable, but considering the DCI x<sub>2</sub> is beneficial for PDCCH overhead reduction (as commented in the last round), we slightly prefer option 3.

For the point raised by Intel that a gNB may currently only support 0<sub>1</sub>/1<sub>1</sub> and not 0<sub>2</sub>/1<sub>2</sub>, we share the similar view with Panasonic that we think the current gNB (R15/16) cannot support RedCap as well, updates at gNB side for support RedCap are necessary, and in our understanding, modifications to support 0<sub>2</sub>/1<sub>2</sub> may be ignorable compare to those main updates.

## **9 – LG Electronics Inc.**

[LG] Please revise LG's preference from option 3 to option 2 on the 1st Round Summary. There was a mistake in writing it, and we wrote an additional comment on the correction.

We still prefer Option 2, and the Option 3 is not acceptable to us. There is no need for RedCap UEs to have different optional features from non-RedCap UEs. We also share the same view on the problem that Intel raised and the FL summarized above.

## **10 – ZTE Corporation**

Option 2 is preferred slightly. However, for RedCap UE, if we want to reduce the PDCCH blocking or save the power assumption brought by blind decoding, both formats set to optional can be more appropriate. Moreover, this would not bring the gNB burden issue.

## **11 – Nokia**

[Nokia] We prefer option 3. The gNB anyway has to support some modifications for RedCap (e.g. with respect to HD-FDD UE) and we do not think option 3 is a large implementation burden given the benefits of compact DCI.

## **12 – Futurewei Technologies**

[FUTUREWEI] Our preference is Opt 3, but it is hard to say that the current optionality of Opt 2 is "unacceptable". We can accept Option 2 if there is some gNB or UE maturity consideration.

## **13 – NTT DOCOMO INC.**

[DOCOMO] We still prefer Option 2 and don't accept Option 3. Compact DCI does not bring enough gain to reduce PDCCH blocking rate. No strong motivation to modify the mandatory/optional capability from non-RedCap UEs

## **14 – Samsung Research America**

[Samsung]: For DCI format X1, there are many redundant bits, which have impact on DL coverage and performance. Keeping the size of DCI 01/1<sub>1</sub> while also not doing anything about coverage/blocking may actually jeopardize RedCap with 1 Rx. So we cannot accept Opt2.

We support Opt 3 as format X2 is more flexible and clean. Regarding the issue raised by Intel, we don't see burden for gNB to support DCI format X2. gNB can configure format x2 same as x1 if necessary.

## **15 – Chengdu OPPO Mobile Com. corp.**

[OPPO] We prefer option2. It is not necessary to make DCI format x2 mandatory for gNB.

<p><b>16 – Ericsson LM</b></p> <p>[Ericsson] Option 2 is our preference. Option 3 is NOT acceptable to us.</p> <p>We agree with Intel’s point. Option 3 will unnecessarily delay the deployment of RedCap. Also, the incurred spec impacts are not justified by the minimal reduction in PDCCH blocking. Therefore, we prefer Option 2, where DCI format 0_2/1_2 is optional, same as for legacy UEs.</p>
<p><b>17 – QUALCOMM JAPAN LLC.</b></p> <p>[Qualcomm] We agree with the comments of Nokia and Samsung. Option 3 is preferred.</p>
<p><b>18 – Intel Corporation (UK) Ltd</b></p> <p>[Intel] Same as before - Option 2 is preferred.</p>
<p><b>19 – Xiaomi Communications</b></p> <p>[Xiaomi] We prefer Option 2</p>
<p><b>20 – SHARP Corporation</b></p> <p>[Sharp] Option 3 is our preference. DCI x_1 requires RRC parameters to enable/disable DCI fields as like MCS/NDI/RV for second TB and CBG. These DCI fields are absolutely not necessary for RedCap UEs. RedCap UEs are not expected to have this kind RRC parameter. Regarding issue raised by Intel, we agree with Panasonic, Nokia and Samsung.</p>
<p><b>21 – InterDigital Communications</b></p> <p>We prefer Option 3 but if the gNB implementation concerns are justified, then we are also fine with Option 2.</p>

3.1.4 <2nd Round Summary>

Views on Opt.2 vs. Opt.3 were captured in Table below:

**Table 4:**

	Supportive Companies	# of Supportive companies
Opt.2	vivo, CMCC,CATT,NEC, Huawei, LGe, ZTE,DoCoMo, OPPO, Ericsson, Intel, Xiaomi, InterDigital (2nd choice)	13
Opt.3	Panasonic, Spreadtrum, Nokia, Futurewei, Samsung, Qualcomm, Sharp, InterDigital (preferred)	8

**[FL4] High Priority Proposal 3-1**

**Regarding DCI format 0\_1/1\_1 and DCI format 0\_2 and 1\_2, select one of the following options**

**-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.**

The following was agreed in Tuesday GTW Session:

**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.

**Figure 11:**

## 3.2 Potential Modification on existing DCI Formats

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.**

### 3.2.1 <1st Round Comments>

**[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.**

**Feedback Form 5: 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.**

**1 – QUALCOMM JAPAN LLC.**

We are ok with P3 and P4. P2 can be FFS.

**2 – Nordic Semiconductor ASA**

We are fine to remove functionalities not applicable to RedCap UEs. It is clear that 2nd CW is not applicable, max 2 layers for RedCap. SUL should not be applicable to RedCap UE, secondary carrier bit is not necessary. It is clear that RedCap UE shall not support CA, so CIF is not present. Optimizations for RV, MCS, etc. are not considered. So we are generally fine with the spirit of P2 and P4 changes.

**3 – vivo Communication Technology**

We think P2 can be considered.

**4 – CATT**

We support P1. In addition, even with P1, current specification already supports removing some unnecessary field, e.g. Carrier Indicator, or reduce field bitwidth, e.g. FDRA, or not configuring some fields, e.g. SCell dormancy indication.

**5 – ZTE Corporation**

P1 is preferred.

In connected mode, PDCCH blocking issue is not identified by RAN1. Moreover, the PDCCH blocking rate can be reduced by UE scheduling based on the existing technologies. Therefore, the compact DCI is not needed.

In initial access, separate (initial) DL BWP, CORESET, search space can be used to address the PDCCH blocking issue.

**6 – Chengdu OPPO Mobile Com. corp.**

[OPPO] We support P1. The presence and size of some fields in existing DCI formats is configurable in current specification. PDCCH blocking rate is not a new issue caused by RedCap UE. Existing methods can address this issue since Rel-15, e.g. separate BWP, CORESET, search space.

**7 – Samsung Research America**

[Samsung] We support P5 as fine scheduling granularity not necessary for RedCap UEs,

We think DCI format x\_2 already excludes fields associated with TB2 as mentioned in P4, and supports configurable bit width for most of the fields mentioned in P2.

## 8 – Futurewei Technologies

[FUTUREWEI] The size of the DCI is a function of many configuration parameters. Once the features are addressed can the size of the DCI be actually determined. At this point, we should strive to make changes to the DCI format only if necessary.

## 9 – Ericsson LM

[Ericsson]

P1, P5, and P7 are being discussed under AI 8.6.1.1. So, we do not need to discuss this under AI 8.6.1.2. However, in general, we are supportive of these features.

P2 and P6: In our view, these optimizations need not be considered in Rel-17.

P3 and P4: FFS. We need to study further if there would be any specification impact if RedCap UEs are to support these features.

## 10 – Ericsson LM

[Ericsson]

(Sorry for the earlier comment. It was meant for Proposal 4-1)

P2: assessment of changes to the DCI fields motivated by the different reduced capabilities for RedCap can be deferred to a later stage.

P3: the added benefit of the new RRC parameters is not clear to us.

P4: There may also be other RRC parameters, in addition to *maxNrofCodeWordsScheduledByDCI*, that can be either removed or need updates to their values. We think this can be handled in RAN2.

P5: We think additional optimization to DCI format x\_2 is not needed.

## 11 – Intel Corporation (UK) Ltd

[Intel]

P1: Agree.

P2: Not necessary as these bit-fields can be reduced to 0 bits by configuration

P3: Not necessary, and this also depends on decision on DCI format usage for RedCap (earlier question)

P4: Optimization of RRC signaling OH by 1 bit can be left to RAN2.

P5: Further optimization for x\_2 is not justified.

## 12 – Panasonic Corporation

[Panasonic] Prefer P1 and P2.

For the purpose of PDCCH blocking perspective, no need to discuss the reduction of DCI size.

For the alignment with other RedCap UEs purpose, some field or some values can be unnecessary. These can be discussed as a kind of "correction".

## 13 – LG Electronics Inc.

[LG] We support P1. We should clarify first whether modification is essential or not.

## 14 – NEC Corporation

[NEC] Support P1. DCI fields irrelevant for RedCap can be 0 bit with existing specification.

<p><b>15 – HUAWEI Technologies Japan K.K.</b></p> <p>[Huawei, HiSi] UL/SUL indicator should be removed from P2.</p>
<p><b>16 – NTT DOCOMO INC.</b></p> <p>[DOCOMO] We prefer P1 as current spec supports 0 bit configuration for the fields inapplicable to RedCap UEs</p>
<p><b>17 – China Mobile Com. Corporation</b></p> <p>[CMCC] P1 can be the starting point, since most of the reduced capability related fields are configurable and can be zero if not configured such as CA, TB2, CBG related fields, etc., or can be reduced, such as FDRA.</p> <p>Then whether bit length of some fields can be reduced due to disable of table indexes can be further studied, such as Antenna port(s) field.</p>
<p><b>18 – Lenovo (Beijing) Ltd</b></p> <p>[Lenovo, Motorola Mobility] We support P1.</p>

### 3.2.2 <1st Round Summary>

**Table 5: Companies Views on Potential Modification on existing DCI Format proposals**

	Supportive	Negative
P1	CATT, ZTE, OPPO, Intel, Panasonic, LGe, NEC, NTT DoCoMo, CMCC, Lenovo [11]	-
P2	Nordic, Vivo, Panasonic [3]	Ericsson (defer to later stage), Intel,
P3	Qualcomm [1]	Ericsson, Intel,
P4	Qualcomm, Apple, Nordic [1]	Ericsson/Intel (handled by RAN2)
P5	Samsung [1]	Ericsson, Intel

### 3.2.3 <2nd Round Comments>

Based on feedback, quite a few companies indicate that most of the reduced capability related fields in non-fallback DCI formats are already configurable and can be zero if not configured and hence no need to modify the existing fields.

#### [FL3] High Priority Question 3-4:

**Is there any existing fields in the non-fallback DCI formats that can NOT be set to '0' bit by proper**

**RRC configuration for Redcap and worth discussing as potential enhancement? Please also clarify which DCI Format is assumed for the answer, i.e., DCI x\_1 or DCI x\_2.**

**Feedback Form 6: Is there any existing field(s) in the non-fallback DCI formats that can NOT be set to '0' bit by proper RRC configuration for Redcap and worth discussing as potential enhancement? Please also clarify which DCI Format is assumed for the answer, i.e., DCI x<sub>1</sub> or DCI x<sub>2</sub>.**

**1 – vivo Communication Technology**

[vivo]It seems true that the concerned fields in non-fallback DCI can be configured by RRC to be zero. The question would then be that whether Redcap UE should expect such RRC configuration which is so obvious, or maybe we can define some default assumptions to save unnecessary RRC configurations. However, we would agree these may not be urgent topic at current stage.

**2 – CATT**

[CATT] Understand the motivation, but given the fact that most of the existing fields can be properly configured to be zero bits or reduced bitwidth, we are not sure what is 'worth discussing' left. By proper definition of RedCap type and related L1 capability, after the gNB acknowledging the RedCap UE, it should be able to properly configure correct RRC parameters to the RedCap UE.

As pointed out by many companies, further reduction of bitwidth, if possible, only achieves marginal gain in coverage.

**3 – China Mobile Com. Corporation**

[CMCC] It seems most of DCI fields related to RedCap in non-fallback DCI format can be set to '0' or reduced accordingly.

**4 – Nordic Semiconductor ASA**

We do not see strong motivation for any changes. Of course we are fine to consider changes case by case, if benefits are worth to consider.

**5 – NEC Corporation**

[NEC] We consider existing DCI formats generally fit well also for RedCap UE.

**6 – HUAWEI Technologies Japan K.K.**

[Huawei, HiSi] Perhaps this should be discussed case by case.

**7 – LG Electronics Inc.**

[LG] As stated by other companies, most of the existing fields of both DCI format x<sub>1</sub> and x<sub>2</sub> that are not needed for RedCap UEs can already be set to zero. Additional optimization on existing fields does not make much difference in terms of PDCCH blocking rate. Therefore we do not prefer any modifications on the existing DCI format.

**8 – ZTE Corporation**

[ZTE]No. The legacy DCI fields are compatible with RedCap DCI fields. We do not see the necessity to discuss the potential enhancement. on the existing DCI fields.

<p><b>9 – Nokia</b></p> <p>[Nokia] Currently, we do not see any field for non-fallback DCI that cannot be set to 0 for RedCap. Therefore we do not see the need to further enhance the DCI fields.</p>
<p><b>10 – Futurewei Technologies</b></p> <p>[FUTUREWEI] These are worth discussing more next meeting (it may be hard to conclude anything now).</p>
<p><b>11 – NTT DOCOMO INC.</b></p> <p>[DOCOMO] No, we haven't found any bitfields which is worth discussing as potential enhancement</p>
<p><b>12 – Samsung Research America</b></p> <p>[Samsung]: We think reduction of MCS field can be considered for both DCI format x_1 and x_2 for RedCap devices. There is no need for RedCap UEs to consider the fine scheduling granularity as legacy UEs, considering small TBS.</p>
<p><b>13 – Ericsson LM</b></p> <p>[Ericsson] We do not see a need to reduce the bit-width of existing DCI fields to '0' (for those that are not possible already). We agree with comments from CATT.</p>
<p><b>14 – QUALCOMM JAPAN LLC.</b></p> <p>[Qualcomm] Regarding the redundant fields in DCI format 0_1/1_1, we think DCI formats 0_2/1_2 are sufficient to cover the bit-width reduction necessary for RedCap UE.</p>
<p><b>15 – Intel Corporation (UK) Ltd</b></p> <p>[Intel] Same view as Nokia.</p> <p>DCI format 0-2/1-2 is fully flexible and hence, no issue.</p> <p>Even for DCI formats 0_1/ 1_1, we do not find a case specifically relevant to RedCap (in the context of omission of the bitfield) wherein the bit-field width cannot be effectively made zero.</p>
<p><b>16 – InterDigital Communications</b></p> <p>We do not see any need for changes.</p>

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## 4 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.

#### 4.1 <1st Round Comments>

##### [FL1] High Priority Question 4-1:

**Is there a need to introduce solution for reducing PDCCH blocking rate for Redcap? If yes, which alternative(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.**

##### **Feedback Form 7: Please provide views on Question 4-1 above.**

###### **1 – QUALCOMM JAPAN LLC.**

We support P4, which helps to reduce the DL signaling overhead and potential PDCCH blocking issues in initial DL BWP. P1 and P5 can also be supported when the channel BW is wider than the max BW of RedCap UE. P2 and P3 can be FFS.

###### **2 – vivo Communication Technology**

[vivo] No severe PDCCH blocking issue was identified in study item phase, as the same BD number as legacy is kept for redcap UEs. If there is any need to reduce the PDCCH blocking probability, existing solutions, e.g. use compact DCI format can be utilized.

Additional enhancements for PDCCH blocking reduction is not considered further in Rel-17

### **3 – Nordic Semiconductor ASA**

The largest challenges are in initial access when gNB channel BW is wide, P5/P7 should address it. P1 is no help in this scenario, since initial DL BWP is applicable only after MSG4. P2/P4 are designed in other AIs and could be optional for RedCap UEs.

### **4 – Spreadtrum Communications**

P1, As we prefer to configure a separate DL BWP for RedCap UEs during initial access and/or after initial access, it is naturally that the Msg.2 and Msg.4 PDCCH can be offloaded to a different BWP, then the PDCCH blocking probability can be reduced.

### **5 – CATT**

Same view as vivo. This is out of scope.

### **6 – ZTE Corporation**

P1, P5.

For initial access, PDCCH blocking should be considered especially if early identification of number of Rx branches is not supported

For connected mode, additional solution is not needed since the PDCCH blocking rate can be reduced by UE scheduling based on the existing RRC parameters/technologies.

### **7 – Nokia**

We have not identified significant PDCCH blocking issue in our analysis. We also believe that existing solutions are available and effective. Therefore, there is no need to introduce new solutions for PDCCH blocking.

### **8 – Chengdu OPPO Mobile Com. corp.**

[OPPO] Same view as vivo and Nokia.

### **9 – Samsung Research America**

[Samsung] We are open to FFS solutions for PDCCH blocking rate reduction. We see the significant increase of the PDCCH blocking rate when UEs require higher CCE ALs due to reduced rx branches, and large connectivity size considering the coexistence of RedCap. For solutions, we prefer P6, which helps to reduce PDCCH overhead, improve DL spectrum efficiency, and reduce PDCCH blocking rate.

### **10 – Futurewei Technologies**

[FUTUREWEI] If compact DCI is made mandatory, these alternatives may not be needed.

### **11 – Ericsson LM**

[Ericsson]

P1, P5, and P7 are being discussed under AI 8.6.1.1. So, we do not need to discuss this under AI 8.6.1.2. However, in general, we are supportive of these features.

P2 and P6: In our view, these optimisations need not be considered in Rel-17.

P3 and P4: FFS. We need to study further if there would be any specification impact if RedCap UEs are to support these features.

#### **12 – Intel Corporation (UK) Ltd**

[Intel] Same view as vivo, Oppo, Nokia.

#### **13 – Panasonic Corporation**

[Panasonic] No need to support new solution. We think the existing solutions are sufficient.

#### **14 – LG Electronics Inc.**

[LG] We don't see the need for solutions for reducing PDCCH blocking rate for RedCap. However, if PDCCH blocking rate is problematic for RedCap, we can consider P1 and P5.

#### **15 – HUAWEI Technologies Japan K.K.**

[Huawei, HiSi] We are open to discuss P1 P4 while not in favor of P5, P6, P7.

Concern for P5: the blocking issue during initial access is not significant. It is also being separately discussed in another thread so prefer to leave the discussion there.

Concern for P6/P7: With some natural modifications caused by reduced UE capabilities to DCI format there could be a compact DCI used thus blocking rate can be reduced. Link adaptation and repetition on PDCCH has relatively large impact on UE implementation as well as impact on legacy PDCCH detection (e.g. when a larger AL is used).

#### **16 – NTT DOCOMO INC.**

[DOCOMO] We think whether existing features are enough or not should be discussed at first, and if deemed necessary, we are open to discuss any enhancements for reducing the PDCCH blocking rate

#### **17 – China Mobile Com. Corporation**

[CMCC] P1 can provide additional CORESET for RedCap UE naturally, and it is discussed in agenda 8.6.1.1, proposal 2.1-2, duplicate discussion should be avoided. If conclusion is made to support separate initial DL BWP in 8.6.1.1, then it can be used to solve PDCCH blocking issue.

For P5, 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. But whether dedicated CORESET can be configured needs more discussion. Currently, one commonControlResourceSet other than CORESET#0 can be configured in PDCCH-ConfigCommon, but the commonControlResourceSet in SIB1 has to be contained in the bandwidth of CORESET#0. And CORESET itself does not provide addition occasion, it relies on search spaces associated with it to provide such TDM occasions.

P3 and P4 introduced in other WIs can also be adopted for RedCap UE to reduced possible PDCCH blocking.

P2 is useful for high density and for industrial wireless sensors use cases where the channel quality may be similar among different UEs in the scenario.

#### **18 – Xiaomi Communications**

[Xiaomi] P4 can be considered

<p><b>19 – Lenovo (Beijing) Ltd</b></p> <p>[Lenovo, Motorola Mobility] If blocking is an issue, then P1, P3, P4, P5 can be considered.</p>
<p><b>20 – Fraunhofer HHI</b></p> <p>We are supportive of P5 and P7 which can help to overcome PDCCH blocking issues.</p>

## 4.2 <1st Round Summary>

**Table 6: Summary of PDCCH blocking Issue**

	Yes	No enhancement for PDCCH blocking issue or FFS
P1	Qualcomm, Spreadtrum, ZTE, Huawei, Lenovo	Vivo/CATT (Out-of-scope), Nokia, OPPO, Ericsson, Intel, Panasonic, LG, CMCC
P2	CMCC	Qualcomm, Vivo, CATT, Nokia, OPPO, Intel, Panasonic, LG
P3	CMCC, Lenovo	Qualcomm, Vivo, CATT, Nokia, OPPO, Intel, Panasonic, LG
P4	Qualcomm, Huawei, CMCC, Xiaomi, Lenovo	Vivo, CATT, Nokia, OPPO, Intel, Panasonic, LG
P5	Qualcomm, Nordic, ZTE, Lenovo, Fraunhofer HHI	Vivo, CATT, Nokia, OPPO, Ericsson, Intel, Panasonic, LG, Huawei,
P6		Vivo, CATT, Nokia, OPPO, Intel, Panasonic, LG, Huawei
P7	Nordic, Fraunhofer HHI	Vivo, CATT, Nokia, OPPO, Ericsson, Intel, Panasonic, LG, Huawei,

## 5 Other aspects

Some other enhancements were brought up by companies as follows:

- P1: Multi-slot repetition for PDSCH is considered as a mandatory feature for RedCap UEs during feature discussions [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.

**Feedback Form 8: Please provide views on Question 5-1 above.**

<b>1 – vivo Communication Technology</b> [vivo] can be discussed at later stage.
<b>2 – Nordic Semiconductor ASA</b> Could be considered, but since no further design is required for that feature, it can be discussed at the end of WI.
<b>3 – CATT</b> Can be discussed later.
<b>4 – ZTE Corporation</b> We can discuss this alter together with other UE features.
<b>5 – Nokia</b> This can be discussed later
<b>6 – Chengdu OPPO Mobile Com. corp.</b> [OPPO] Can be discussed later.
<b>7 – Samsung Research America</b> [Samsung] No need for now. Can be discussed later in UE feature discussion if necessary.
<b>8 – Futurewei Technologies</b> [FUTUREWEI] Can be discussed later
<b>9 – Ericsson LM</b> [Ericsson] Can be discussed in the later stage.
<b>10 – Intel Corporation (UK) Ltd</b> [Intel] We see the relevance but also agree that it can be considered later.
<b>11 – SHARP Corporation</b> [Sharp] Same view as other companies. Can be discussed later.
<b>12 – Panasonic Corporation</b> [Panasonic] P1 can be discussed in later UE feature stage together with others.

<p><b>13 – LG Electronics Inc.</b></p> <p>[LG] This can be discussed in the later UE features stage together with others. This feature has been optional for non-RedCap UEs, which could be the same for RedCap UEs if there is no consensus otherwise.</p>
<p><b>14 – QUALCOMM JAPAN LLC.</b></p> <p>[Qualcomm] Let’s re-visit P1 at a later time.</p>
<p><b>15 – NTT DOCOMO INC.</b></p> <p>[DOCOMO] Can be discussed during UE feature discussion</p>
<p><b>16 – China Mobile Com. Corporation</b></p> <p>[CMCC] Can be discussed during UE features discussion</p>
<p><b>17 – Xiaomi Communications</b></p> <p>[Xiaomi] Can be discussed in the later phase</p>
<p><b>18 – Sierra Wireless</b></p> <p>[Sierra] Possibly a good idea but can be discussed later</p>

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## 6 Agreements/Conclusions

The following was agreed under this agenda:

**Agreement:**

- Redcap UE is mandated to support at least DCI format 0\_0/1\_0.

**Agreement:**

For UE capability signalling, the number of Rx branches for RedCap is implicitly indicated by the corresponding capability parameter *maxNumberMIMO-LayersPDSCH* in the existing UE capability framework.

- Detailed signalling is up to RAN2

**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.

**Figure 12:**

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## 7 References

RP-210918 “Revised WID on support of reduced capability NR devices”, RAN#91e, Nokia, Ericsson.

R1-2104027 RAN1 agreements for Rel-17 NR RedCap Rapporteur (Ericsson)

R1-2104180 Reduced number of Rx branches for RedCap Ericsson

R1-2104189 Discussion on RX Branch Reduction for RedCap UEs FUTUREWEI

R1-2104284 Reduced number of Rx branches for RedCap Huawei, HiSilicon

R1-2104366 Discussion on reduced number of Rx branches vivo, Guangdong Genius

R1-2104527 Discussion on reduced number of Rx branches CATT

R1-2104544 Aspects related to reduced number of Rx branches Nokia, Nokia Shanghai Bell

R1-2104617 Discussion on reduced number of Rx branches CMCC

R1-2104678 RX Branch Reduction for RedCap UE Qualcomm Incorporated

R1-2104711 Discussion on reduced number of UE Rx branches ZTE, Sanechips

R1-2104783 Discussion on reduced number of UE Rx branches OPPO

R1-2104912 On reduced number of Rx branches for RedCap Intel Corporation

R1-2105111 On reduced number of Rx branches for Redcap Apple

R1-2105218 Reduced number or Rx branches for RedCap Lenovo, Motorola Mobility

R1-2105317 Discussion on reduced number of RX branches for RedCap UEs Samsung

R1-2105430 Aspects related to the reduced number of Rx branches of RedCap LG Electronics

R1-2105568 Aspects on reduced number of Rx branches Xiaomi

R1-2105594 Discussion on aspects related to reduced number of Rx branches NEC

R1-2105636 Discussion on reduced minimum number of Rx branches Sharp

R1-2105704 Discussion on reduced minimum number of Rx branches for RedCap NTT DOCOMO, INC.

R1-2105728 Aspects related to reduced number of Rx branches Panasonic Corporation

R1-2105737 On reduced number of Rx branches for RedCap UEs MediaTek Inc.

R1-2105747 Reduced number of Rx branches for RedCap UEs InterDigital, Inc.

R1-2105752 Discussion on reduced number of Rx branches China Unicom

R1-2105883 On aspects related to reduced number of Rx branches Nordic Semiconductor ASA

R1-2104287	RAN1 aspects of RedCap UE type and identification	Huawei, HiSilicon
R1-2104369	Higher layer support for RedCap	vivo, Guangdong Genius
R1-2104431	Discussion on early indication for RedCap UE	Spreadtrum Communications
R1-2104530	Discussion on higher layer support of RedCap	CATT
R1-2104546	Higher layer support of Reduced Capability NR Devices	Nokia, Nokia Shanghai Bell
R1-2104562	Design consideration for Higher layer support of RedCap	Sierra Wireless, S.A.
R1-2104620	Discussion on higher layer support of RedCap UE	CMCC
R1-2104714	Higher layer support of Reduced Capability NR devices	ZTE, Sanechips
R1-2104785	Mechanism in higher&PHY layer for Reduced Capability NR Devices	OPPO
R1-2104853	Discussion on RAN1 aspects for RAN2-led features for RedCap	China Telecom
R1-2104915	On RedCap UE types: Definition, access control, and identification	Intel Corporation
R1-2105220	UE identification and access control for RedCap	Lenovo, Motorola Mobility
R1-2105638	RAN1 aspects for RAN2-led features for RedCap	Sharp
R1-2105885	On RedCap UE early identification	Nordic Semiconductor ASA