**3GPP TSG-RAN WG2 Meeting #112 electronic R2-200xxxx**

**Elbonia, Nov 2nd – 13th 2020**

**Agenda item:** 8.12.2.1

**Source:** Intel Corporation

**Title:** Report of [Post111-e][913][REDCAP] Definition and constraining of reduced capabilities (Intel)

**Document for:**  Discussion and decision

# Introduction

This contribution provides report for RAN WG2 email discussion:

* [Post111-e][913][REDCAP] Definition and constraining of reduced capabilities (Intel)

Scope: Continue to discuss the UE capability framework, how to define and constrain reduced capabilities, addressing the open issues and discussing potential solutions

Intended outcome: email discussion summary

 Deadline: Oct 15th , 2020

Rapporteur proposes to divide the discussion in two phases:

**Phase 1**: Based on the contributions in last meeting, and the agreements from RAN1:

* To collect companies’ view on potential scope/issues of the email discussion;
* To collect additional issues/solutions;

Deadline: Sep 30th

**Phase 2**: Companies are invited to provide views on the issues/solutions collected/clarified in phase 1.

Deadline: Oct 15th

To make it easier to find the correct contact delegate in each company for potential follow-up questions, the rapporteur encourages the delegates who provide input to provide their contact information in this table:

|  |  |
| --- | --- |
| Company | Delegate contact |
| COMPANY\_NAME | NAME (email@address.com) |
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| Qualcomm | linhaihe@qti.qualcomm.com |

# Discussion

## Phase 1

### How to define the reduced capabilities

Based on [3], RAN2 discussed the issues on how to define and constrain reduced capabilities and agreed [2]:

Agreements:

1. At least for device type identification and access restriction (including initial access), the network needs to know whether the UE is redCap UE or not. FFS on whether based on explicit or implicit signalling.
2. The existing UE capabilities framework is used as baseline to indicate the capabilities of a RedCap UE (this does not imply anything on the reporting of the device type, if the need for a device type will be agreed)
3. The number of device types should be minimised, to reduce market fragmentation, and introduced only where essential to control UE accesses and differentiate them from legacy R15/R16 and non-Redcap R17 UEs, (e.g. number of Tx/Rx antennas, maximum supportable BW, etc.). The exact composition of the set of L1 capabilities of the device type can be discussed by RAN1
4. Discuss in normative phase on whether to signal (and in case how) a Device type and its associated capabilities (the reduced set of capabilities) is captured in specifications, and whether device type is indicated as part of UE capability;

Regarding the open issue “*FFS on whether based on explicit or implicit signalling.*”, for device type identification and access restriction, Rapporteur believes it should be discussed or resolved once the solutions on device type identification is clear.

For the issue how to define the reduced capabilities, RAN2 have agreed “*2. The existing UE capabilities framework is used as baseline to indicate the capabilities of a RedCap UE*”, however the details are still missing. During the offline discussion in [3], following is mentioned:

* *“We agree to consider the current signalling structure as a baseline, but we think the capabilities restriction for the defined device type should be specified very clearly in the specification (maybe separate section in TS38.306) to avoid unnecessary complexity for the UE and gNB to implement corresponding capabilities, including:*
	+ *Mandatory/Minimum set of capabilities for the defined device type*
	+ *Capabilities (or specific values for certain capability) that only apply to the defined device type*
	+ *Capabilities (or specific values for certain capability) not apply to the defined device type”*
* “*For example, as part of the current NR capabilities we have:*
	+ *Min capabilities all UEs support (not signaled explicitly)*
	+ *Optional capabilities (signaled explicitly)*

*Similarly, for RedCap we expect:*

* + *Min capabilities all RedCap UEs support (only identifier needs to be signaled)*
	+ *Optional capabilities (signaled explicitly)”*

On top of high level agreements “*2. The existing UE capabilities framework is used as baseline to indicate the capabilities of a RedCap UE*”, it would be good to further clarify:

* Whether similar to current NR non-RedCap UE capabilities, RedCap UE capabilities can also be categorized as:
	+ *Min capabilities all RedCap UEs support (i.e. mandatory for RedCap UE);*
	+ *Optional capabilities (signaled explicitly)*

**Question 1-1: Do companies agree that similar to current NR non-RedCap UE capabilities, RedCap UE capabilities can also be categorized as:**

* **Min capabilities all RedCap UEs support (i.e. mandatory for RedCap UE) if identified;**
* **Optional capabilities (signaled explicitly)**

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| **Company** | **Yes/No** | **Remark**  |
| Intel | Yes |  |
| Apple | Yes | We agree there would be atleast some aspects all RedCap UEs are expected to support mandatorily (atleast needed for initial aspects) and so we cannot define capabilities for all of these. |
| Sharp | Yes | The mandatory capabilities without signaling for non-RedCap UE but mandatory capabilities with signaling for RedCap UE are also possible. |
| OPPO | Yes | According to RAN1 agreements, at least 20MHz bandwidth for FR1 is mandatory for all RedCap UEs. |
| ZTE | Yes | We agree Redcap UE capabilities can be categorized as “mandatory ones” and “optional ones”, and this provides flexibility to market planning and product implementation. But we are wondering whether we need to define “min capabilities” with different values for different Redcap types. E.g. differentiate FR1, FR2.  |
| NEC | Yes |  |
| Huawei, HiSilicon | Yes |  |
| Spreadtrum | Yes |  |
| LGE | Yes |  |
| Ericsson | Yes |  |
| MediaTek | Yes |  |
| Qualcomm | Yes |  |

For current NR non-RedCap UE capabilities, the minimum capabilities, e.g. mandatory bandwidth, e.g. are not signalled, and may not be applied for RedCap UE (depends on RAN1 agreements). How to handle such capabilities?

**Question 1-2: How to handle non-RedCap UE’s mandatory capabilities without signaling if they are not applied for RedCap UE?**

* **Alt 1: (As commented in the offline discussion [3]), The minimum UE capability requirements for a RedCap device type, that are different from those for non-RedCap UEs, are defined in the specifications, and only the RedCap device type may be indicated as part of the capability signaling.;**
* **Alt 2 [7]:**  **For a RedCap device type, define new capability signaling fields for the features that are mandatory w/o capability signaling for non-RedCap UEs but are optional or not supported for the RedCap device type.**
* **Alt 3: The minimum UE capability requirements for a RedCap device type, that are different from those for non-RedCap UEs, are defined in the specifications. That is:**
	+ **Mandatory features for non-RedCap UE that are not supported for RedCap UE;**
	+ **Mandatory features for non-RedCap UE that are optional for RedCap UE;**

**For a RedCap device type, define new signaling fields in UE Capability for the features that are mandatory w/o capability signaling for non-RedCap UEs but are optional for Redcap UEs.**

**In addition, the network needs to know whether the UE is RedCap UE or not in order to know how to handle UE capabilities (that is, when these fields are not included, it should be possible to differentiate whether it is because it is a non-Redcap UE or because it is not supported by a RedCap UE).**

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| **Company** | **Alt 1, Alt 2 or others** | **Remark**  |
| Intel | Alt 3 | For mandatory features w/o capability signalling supported by non-RedCap UE, there are 3 scenarios:Scenario 1 it is not supported for RedCap UE;Scenario 2 it is optional for RedCap UE;Scenario 3 it is still mandatory supported for RedCap UE;To our understanding:Alt 1 cannot work well for scenario 2 since it cannot indicate optional features (mandatory for non-RedCap UE)Alt 2 cannot work well for scenario 1 since currently the absence of these capability means “mandatory”.To solve the problem, we may combine alt 1 and 2 as:**To address scenario 1:**The minimum UE capability requirements for a RedCap device type, that are different from those for non-RedCap UEs, are defined in the specifications. That is:o Mandatory features for non-RedCap UE that are not supported for RedCap UE;o Mandatory features for non-RedCap UE that are optional for RedCap UE;**To address scenario 2:**For a RedCap device type, define new signaling fields in UE Capability for the features that are mandatory w/o capability signaling for non-RedCap UEs but are optional for Redcap UEs.In addition, the network needs to know whether the UE is RedCap UE or not in order to know how to handle UE capabilities (that is, when these fields are not included, it should be possible to differentiate whether it is because it is a non-Redcap UE or because it is not supported by a RedCap UE). |
| Apple | Modified version of Alt-3  | We agree with the ambiguity that can arise from the scenarios and different interpretations. In addition to the Alt-3, for the fields that are mandatory to non-RedCap UEs, but optional to RedCap UEs, we also need to distinguish what the absence of a field means: * Whether the RedCap UE supports the mandatory functionality like the non-RedCap UEs
* Whether the RedCap UE does not support this functionality at all.

We think, this needs to be clarified for the new capability signaling we add for RedCap UEs. It can be done for each of the fields, are as a group…but we think it might be better to do for each of such capabilities. |
| Sharp | Alt3 | The mandatory capabilities without signaling for non-RedCap UE but mandatory capabilities with signaling for RedCap UE are also possible and need to be defined in the specifications. |
| OPPO | Alt3 with comments | We are fine with alt3 to cover both cases only if they are confirmed by RAN1:o Mandatory features for non-RedCap UE that are not supported for RedCap UE;o Mandatory features for non-RedCap UE that are optional for RedCap UE;For the moment, we think the first case has been confirmed, e.g. mandatory bandwidth. The second case is still up to RAN1. |
| ZTE | Modified version of Alt3 | In our understanding, for the fields that are mandatory for non-Redcap UEs, there are following cases:Case1: The Redcap UE mandatorily supports the feature with the same value;Case2: The Redcap UE mandatorily supports the feature, but with different value (e.g. bandwidth value);Case3: The Redcap UE optionally supports the feature;Case4: The Redcap UE does not support the feature at all. For Case1, 2 and 4, we think they can be defined in specification. For case 3, as indicated in Alt-3, new signalling field can be introduced for Redcap UEs.  |
| NEC | Alt 3 | At this moment, we share the views from Intel. On the other hand, we are wondering how/whether RAN2 should go into details before knowing which capabilities (e.g. among legacy mandatory capabilities) are not supported by the RedCap UEs. Probably better to wait for RAN1 progress?  |
| Huawei, HiSilicon | Alt-3 with comment | We are globally fine with the proposed principles in Alt-3.In addition, to reduce the complexity for the UE and the network to implement the UE capabilities, we think optional features for non-RedCap UE that are not supported for RedCap UE also need to be specified in the specifications, e.g. capabilities related to DC does not apply to RedCap UE. |
| Spreadtrum | Agree with Huawei |  |
| LGE | Alt-1 or Alt-3 |  |
| Ericsson | Modified Alt 3 / new alt | We suggest to first study which capabilities would fall into which category (cf. Intel scenarios) before jumping into conclusions on exact definitions and solutions. For example, is it clear there are some mandatory (w/o signaling) capabilities which would be optional for RedCap? As the existing mandatory features/capabilities are not listed in TS 38.306, we are hesitant to introduce such just for RedCap purpose, if that is the intention in Alt-3. We should look into how e.g. mandatory LTE features were handled when Cat-M1/M2 were introduced. Preferably the RedCap UE definition lists or explains which mandatory features are not supported. In general, we have agreed to discuss the details of capability signaling in normative phase, and typically capabilities are discussed late in normative phase. For the study phase and TR we can explain the issues, do a study of the existing capabilities/features (e.g. which would be optional) and present the different possible solutions. |
| MediaTek | Alt 1 (or 3) i.e. identifier + optional capabilities | If RedCap UEs provide a RedCap identifier (associated with the new set of mandatory features for RedCap UEs), the network would interpret capability fields in Scenario 1 and Scenario 2 differently for RedCap and non-RedCap UEs. For now, we should first look at which set of features fall in scenarios 1/2/3 before going into signaling design details. |
| Qualcomm | Part of Alt 3 | We can support the principles behind Alt 3. Regarding the last statement in Alt 3, i.e. “network needs to know whether the UE is RedCap UE or not in order to know how to handle UE capabilities”, we think UE needs to indicate it is a RedCap for network to ensure its constrained use and that indication will be sent in connection request before UE capability signaling. Therefore, RedCap type indication does not need to be included in UE capability signaling.Lastly, we share similar views with companies above that it is a bit too early to discuss this level of details in capability signaling, especially not knowing yet what each category of features may include. |

Some contributions [8], [9], discussed whether multiple reduced capability sets should be supported. Rapporteur would suggest to leave it to RAN1 since it is tightly related to the issue “the number of device type”.

**Question 1-3: Any additional issues need to be addressed in the email discussion on how to define the reduced capabilities?**

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| **Company** | **Issues** |
| Intel | As discussed in Question 1-2, Alt 3, the network needs to know whether the UE is RedCap UE or not in order to know how to handle UE capabilities (that is, when these fields are not included, it should be possible to differentiate whether it is because it is a non-Redcap UE or because it is not supported by a RedCap UE). But the question is how?We see below options, and this should be discussed in the email discussion. **Option 1:** RedCap device type is indicated as part of the capability signaling**Option 2:** Define a new IE specifically for RedCap UEs containing these additional Redcap specific capabilities that is included only by Redcap UEs.**Option 3:** The network obtains the RedCap based on identification solution during initial access, and forwards it to target during Handover. |
| Apple | Regarding comment by Intel, we think op-2 is simpler, and this would be added as a non-critical extension, so easier to address the gNBs which have not implemented RedCap. We can bunch all the RedCaps UEs into a struct, or add extensions in diff areas of the capability. If done correctly, Op-2 can cover Op-1’s functionality.We also think the target gNB has to implement RedCap, to serve RedCap UEs. |
| Sharp | Depends on the discussion on identification. If there is a solution for identification, we can use the information for UE capability anyway. |
| OPPO | We think option 1 and 2 mentioned by Intel are needed after RAN1 confirms the two cases in Question 1-2. The final decision would be pending RAN1 input. |
| ZTE | Regarding the question raised by Intel, seems we have made agreement that it will be discussed in WID phase?

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| 4. Discuss in normative phase on whether to signal (and in case how) a Device type and its associated capabilities (the reduced set of capabilities) is captured in specifications, and whether device type is indicated as part of UE capability; |

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| Huawei, HiSilicon | Agree with the issue raised by Intel, i.e. how does the network know whether the UE is RedCap UE. We are fine to discuss the listed options in this email discussion. |
| Spreadtrum | Maybe we can discuss this issue after the definition of device type. |
| Ericsson | Note that early identification is also being discussed in another context as well. The details we have agreed to discuss further during the normative phase.  |
| MediaTek | Agree with the issue raised by Intel and the set of options for discussion. |
| Qualcomm | We prefer Option 3, as RedCap need to identify itself during connection setup, e.g. for the purpose of ensure RedCap is only used for intended use cases. |

### Constraining of reduced capabilities

How to ensure the RedCap UE is only used for intended use cases were discussed in [3]-[6]. Following potential solutions were mentioned:

* **Option 1 [5]**:

*One potential problem could be when a RedCap UE requests a service that does not match the reduced UE capabilities. This would be similar to if e.g. an NB-IoT UE requested a video call to be set up. RAN can already reject an RRC connection establishment attempt e.g. based on the establishment cause provided in Msg3 or through higher layer mechanisms.*

RAN can reject an RRC connection establishment attempt for a RedCap UE if the service the UE requested is not allowed for the RedCap UE. That is, the RAN needs to identify whether the UE is a RedCap UE or not, and be aware of the requested service, e.g. based on the cause value or other ways.

Note, the details of identification should be discussed in the email discussion [Post111-e][914][REDCAP] UE identification and access restrictions (Huawei).

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| * + **Opt. 1**: During Msg1 transmission, e.g., via separate initial UL BWP, separate PRACH resource, or PRACH preamble partitioning.
	+ **Opt. 2**: During Msg3 transmission.
	+ **Opt. 3**: Post Msg4 acknowledgment.
		- **E**.g., during Msg5 transmission or part of UE capability reporting.
	+ **Opt. 4:** During MsgA transmission (subject to support of if 2-step RACH)
	+ Other options are not precluded.
	+ Note: This study intends to establish feasibility of, and pros and cons for the identified options from RAN1 perspective, without any intention of down-selection without guidance from RAN2.
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* **Option 2 [6]: subscription validation**

During RRC connection setup, UE indicates it is a RedCap UE to core network, e.g.

• UE includes this indication in its NAS signaling message to core network; core network then informs RAN of UE’s RedCap type; or

• UE includes this indication in its RRC connection establishment message to RAN; RAN then informs core network of UE’s RedCap type in its Initial UE Context message to core network.

After network receives UE’s RedCap indication, it validates UE’s indication against its subscription plan, which includes information such as the set of services allowed for the UE. Based on the outcome of this validation, network then decide whether to accept or reject UE’s registration request. For example, network may reject UE if UE indicates RedCap but its subscription does not include any RedCap-specific services.

* **Option 3 [6]. verification of RedCap UE**

Network can additionally perform capability match procedure between UE’s reported radio capabilities and the set of capability criteria associated with UE’s RedCap type, to prevent a hacked or misconfigured UE from falsely reporting as a RedCap UE.

 **Option X:**

In Phase 1, companies are invited to provide clarifications on the options as above, and add additional options if any.

**Question 1-4: Any comments on the wording of the options described as above?**

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| **Company** | **Remark** |
| ZTE | **On option1:**One potential problem could be when a RedCap UE requests a service that does not match the reduced UE capabilities.We think it is more appropriate to use “reduced device type” instead of “reduced UE capabilities” , we understand the intention is that RAN can obtain the device type and corresponding minimal requirement during RRC setup procedure, then service rejection can be triggered if a certain cause value is not supported for the RedCap type. However, RAN has not received UE capabilities at RRC setup procedure, thus using reduced device type seems more accurate.**On option2:**During RRC connection setup, UE indicates it is a RedCap UE to core network, e.g. • UE includes this indication in its NAS signaling message to core network; core network then informs RAN of UE’s RedCap type; or• UE includes this indication in its RRC connection establishment message to RAN; RAN then informs core network of UE’s RedCap type in its Initial UE Context message to core network.We understand both RAN and CN can obtain the Redcap type information, RAN obtains via Uu interface identification/capability reporting, and CN obtains via NAS signalling (subscription information). Thus for the red sentence in first bullet, it is unclear why CN will inform RAN of UE’s Redcap type, does it imply that RAN should double check whether the Redcap type obtained from RAN matches the one forwarded by CN? In our understanding, this “double check” can be performed by CN, and CN can reject the UE when mismatch happens, this is covered by the second bullet. So can company clarify the red sentence in first bullet? Otherwise, we prefer to remove it. In addition, for the red sentence in second bullet, since we haven’t concluded whether explicit indication will be used in RRC message, maybe it is more appropriate to modify it as:“UE informs~~includes~~ this indication during~~in~~ its RRC connection establishment procedure~~message~~ to RAN” |
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**Question 1-5 Any additional options for the network to ensure the RedCap UE is only used for intended use cases?**

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| **Company** | **Additional options** |
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**Question 1-6 Any other issues need to be addressed in the email discussion on the constraining of reduced capabilities?**

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| **Company** | **Issues** |
| ZTE | Whether all the optional capabilities defined for non-RedCap UE are applicable to RedCap UE? In our view, there are two alternatives:* Alt1: All the optional capabilities defined for non-RedCap UE are applicable to RedCap UE. In this case, the RedCap UE is allowed to support the “high end” capability based on the capability signalling, which may extend the scenarios of RedCap UE if it is allowed by the subscription information (e.g. low-end mobile phone).
* Alt2: Only limited optional capabilities defined for non-RedCap UE are applicable to RedCap UE. In this case more discussion are needed to understand which legacy optional capability are allowed for RedCap UE.

If Alt2 is preferred, regarding the capability signaling, we think it might be easier to introduce a new container for Redcap UEs, only includes the capabilities that are applicable to Redcap UEs.  |
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## Phase 2 discussion

### How to define the reduced capabilities

### Constraining of reduced capabilities

# Summary

To be added:

# Reference

[1] Chairman's Notes RAN1#102-e v022

[2] R2-2008122 report from R16 eMIMO-CLI-PRN-RACS - R17 NTN-REDCAP breakout session

[3] R2-2008191 Summary of offline 109 - Reduced capability signalling framework Intel

[4] R2-2006751 Reduced capability signalling framework Intel Corporation

[5] R2-2006911 Framework and Principles for Reduced Capability Ericsson

[6] R2-2006605 Defining and constraining UEs with reduced capabilities Qualcomm Inc

[7] R2-2007110 RedCap UE characterization and access restriction Apple

[8] R2-2007400 Discussion on how to define reduced capability devices LG Electronics UK

[9] R2-2007011 On definition and constraint of reduced capabilities CATT