3GPP TSG-RAN WG2 Meeting#113-e Draft\_R2-2102017

Online, January 25th - February 5th 2021

Agenda Item: 8.12.2.2

Source: Huawei

Title: Summary of offline 107 - [REDCAP] L2 capabilities and UE types

Document for: Discussion and Decision

# Introduction

This document is for the following offline discussion on L2 capabilities and UE types:

* [AT113-e][107][REDCAP] L2 capabilities and UE types (Huawei)

Scope: based on the proposals in [R2-2101255](file:///C:/Data/3GPP/Extracts/R2-2101255%20Higher%20layer%20capabilities%20and%20procedural%20impacts%20of%20RedCap%20UE.doc), [R2-2100310](file:///C:/Data/3GPP/Extracts/R2-2100310_Definition%20of%20RedCap%20UEs.docx) and [R2-2100460](file:///C:/Data/3GPP/Extracts/R2-2100460_UE%20type%20definition%20and%20constraining%20for%20RedCap%20UEs.doc), discuss:

1. which "reduced L2 capabilities" can be listed as possible enhancements in the TR
2. which impacts on procedures for RedCap UEs can be described in the TR
3. which pros and cons to have only one vs multiple RedCap UE types can be listed in the TR

For all the aspects (and namely for 3), the intention of this offline is to describe options and implications in the TR, not to down-select any alternatives

Initial intended outcome: Summary of the offline discussion with:

* + - List of proposals for agreement
    - List of proposals that require online discussions
    - Corresponding TP for the TR

Initial deadline (for companies' feedback): Monday 2021-02-01 11:00 UTC

Initial deadline (for rapporteur's summary in R2-2102017): Monday 2021-02-01 17:00 UTC

Proposals marked "for agreement" in R2-2102017 not challenged until Tuesday 2020-02-02 10:00 UTC will be declared as agreed by the session chair. For the rest the discussion will continue online.

This offline discussion is based on the proposals in the following contributions:

R2-2101255 Higher layer capabilities and procedural impacts of RedCap UE Huawei, HiSilicon

R2-2100310 Definition of RedCap UEs Qualcomm Incorporated

R2-2100460 UE type defination and constraining for RedCap UEs vivo, Guangdong Genius

# Discussion

The following issues will be discussed according to the scope of this offline discussion:

* Reduced L2 capabilities
* Impacts on procedures for RedCap UEs
* Pros/cons to have only one RedCap UE type v.s. multiple RedCap UE types

According to the chairman guidance, the intention of this offline is to describe options and implications in the TR.

## Reduced L2 capabilities

In RAN2#111e meeting, it was agreed that the reduction of upper layer capabilities is FFS:

FFS:

1. Whether reduction of upper layer capabilities should be considered is FFS (in any case no email discussion until the next meeting on this)

Regarding reduction of upper layer capabilities, proposals from above contributions are listed below:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2100310 | Qualcomm Incorporated | Proposal 3. Make the following upper-layer UE capabilities optional for RedCap UEs:   * Maximum number of DRBs; * Total layer-2 buffer size; * 18-bit sequence number field for PDCP and RLC AM; * RRC processing delay. |
| R2-2101255 | Huawei, HiSilicon | Proposal 1: Consider to reduce the number of DRBs to be mandatorily supported for RedCap UE and allow the UE to report the number of supported DRBs.  Proposal 2: Consider to reduce the length of PDCP and RLC AM SN to be mandatorily supported for RedCap UE (e.g. mandatory 12-bit SN). |

In summary, reduction for the following four higher layer capabilities are proposed:

* Maximum number of DRBs;
* Total layer-2 buffer size;
* 18-bit sequence number field for PDCP and RLC AM;
* RRC processing delay.

Companies are invited to provide comments on which the above four higher layer capabilities can be reduced.

**Question 1a.** Do you support reducing the maximum number of DRBs mandatory supported by RedCap UEs?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | We are ok with reduction in number of DRBs, since some RedCap UEs like surveillance do not need many DRBs to support.  This can be a capability at the UE. |
| Qualcomm | Yes | We notice that many use cases for RedCap UEs (e.g. sensors or low end wearables) do not need the current maximum number of DRBs (8), which was selected based on the need of premium eMBB UEs. Since maximum number of DRBs directly affects the buffer size requirement of a UE chip, smaller maximum number of DRBs can help reduce the buffer size and hence the cost of a RedCap UE. |
| Ericsson | TBD | We can consider possible reduction in DRBs once it is clear what all functionality is supported by a RedCap UE, i.e., during the WI phase.  However, even if for some use cases and UEs reduction in DRBs would be possible, we would like to avoid fragmentation and keep in mind forward compatibility with future features. |
| Huawei, HiSilicon | Yes | The large number of DRBs to be mandatorily supported contributes to support multiple traffic types. However, according to the use cases of RedCap UE, the traffic types of RedCap UE will be limited. Moreover, the larger number of DRBs to be mandatorily supported will increase the cost of memory. So, the maximum number of DRB mandatorily supported by RedCap UE should be reduced.  Thus, we propose to reduce the maximum number of DRBs mandatory supported by RedCap UEs to 8. |
| MediaTek | Yes | With limited traffic types defined for RedCap use cases and a goal to reduce complexity, a reduction in max number of DRBs is desirable. The details can be decided in the WI phase |
| Nokia, Nokia Shanghai Bell | Yes | RedCap use cases should suffice with less DRBs, however, the exact number can be discussed in the WI phase. |
| Futurewei | Yes | RedCap use cases may not need large number of DRBs. |
| Sierra Wireless | Yes | In principle the intent is to have a simpler device |
| vivo | Yes with comments | We agree that RedCap UEs may not need 8 DRBs for some use cases. But we need to first identify how much impact on the cost of the devices for this Max. number of DRBs first. After that, we could discuss what the exact number of DRBs is for RedCap UEs. |
| Samsung | Yes | We support the proposal in principle. |
| CATT | Yes | From RedCap use case point of view we think it is possible to relax requirements from this perspective. |
| ZTE | Yes | If some RedCap use case can be identified that larger number of DRBs is not needed, it is reasonable to reduce this maximum DRB number requirement to reduce complexity and cost. |
| OPPO | Yes | Agree that RedCap UEs may not need to support large number of DRBs. Detailed number should be discussed in the WI phase. |
| Sequans | Yes | Limited traffic types are expected. Exact number fore reduction can be determined in the WI phase. |
| DENSO | Yes | Whilst 8 DRBs may not be needed in practice, only one DRB is not sufficient for potential use cases for RedCap UEs. A reasonable number needs to be decided in the WI phase. |
| Xiaomi | Yes | We are ok with reduction in number of DRBs. |
| LGE | Yes with comments | RedCap UEs may not need to support 8 DRBs but we are not the maximum number. We can discuss the details in the WI phase. Same comment as Ericsson. |
| Lenovo | Yes | It is fine to limit the number of DRBs to reduce the cost of a RedCap UE, but also needs to consider the forward compatibility. |
| Intel | TBD | We share the view with Ericsson. It can be discussed during the WI phase once the supported functions are clear for RedCap UE. |
| Facebook | TBD | We shared the same view as Intel and Ericsson. |

**Summary:**

20 companies provided comments on reducing the maximum number of DRBs mandatory supported by RedCap UEs:

* 17 companies think that RedCap uses cases do not need large number of DRBs thus agree to reduce the maximum number of DRBs mandatory supported by RedCap UEs.
* 3 company also agrees to consider possible reduction in DRBs but thinks it is better to decide this in WI phase when functionality supported by a RedCap UE is clear.

**Proposal 1: Capture ‘maximum number of DRBs mandatory supported’ in the TR as one L2 capability which can be reduced for RedCap UEs.**

**Question 1b.** Do you support reducing the total layer-2 buffer size for RedCap UEs compared with the value required by Section 4.1.4 in TS 38.306?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | We are ok with this but | L2 buffer size is anyway something that the gNB can use as a parameter in scheduling. And since there is no CA or DC, it’s even simpler now and it’s transparent to how the UE implements this. So we are not sure what needs to be changed even with a reduction in DRBs. |
| Qualcomm | Yes | Total lay-2 buffer size is used by gNB for scheduling. What we have found in field studies is that for most applications, especially those do not have high data rates, do not need the entire L2 buffer specified in 38.306 to achieve good throughput. Relaxing this requirement hence can help reduce buffer size and hence cost of RedCap Ues.  This reduction can be signalled as a fraction (e.g. 50%) of the “theoretical” total L2 buffer size as a UE capability to network. |
| Ericsson | Yes, later | This sounds reasonable as maximum BW and MIMO layers are reduced (and no CA/DC support has been agreed). We can come back to the details once all options have been worked out related to the physical layer complexity reduction techniques. |
| Huawei, HiSilicon | No | The current L2 buffer size is calculated based on UL/DL peak data rate and RTT time, and the UL/DL peak data is calculated based on bandwidth, modulation order, and numerology and so on. Since the bandwidth and maximum modulation order of RedCap UE has been reduced, the DL/UL peak data and the L2 buffer size of RedCap UE also will be reduced accordingly.  The motivation of further reducing this value is not clear. Furthermore, it should be avoided to modify the basic logic of the current L2 buffer size definition in 38.306. |
| MediaTek | No | While a reduction in L2 buffer size is desirable for RedCap devices to lower its memory requirements, we agree with Huawei that with peak data rate reductions for RedCap, L2 buffer requirements of RedCap devices are implicitly reduced.  A further reduction would imply changes to RLCRTT times (38.306, 4.1.4), which have not been modified for RedCap. We prefer to leave the L2 buffer requirements definition in 38.306 untouched. |
| Nokia, Nokia Shanghai Bell | Yes, but | The maximum data rate in both UL and DL used in the formula in TS 38.306 is what determines the buffer size. When these values are defined, the buffer size will be reduced as Huawei also explains. |
| Futurewei | No | L2 buffer requirement rule in 38.306 should be maintained. The actual L2 size would be adjusted as peak data rate is reduced in RedCap device. |
| Sierra Wireless | Yes | Agree with Ericsson |
| vivo | No? | As we understand, Layer-2 buffer size is calculated based on the bandwidth, MIMO layer and sequence numbers. While these capabilities have been reduced based on RAN1 discussion. So we understand that Layer-2 buffer size has been implicitly reduced naturally. In this way, we would like to check with proponent, what more is needed for specification? |
| Samsung | No | We share the view with Huawei and MediaTek that L2 buffer requirements of RedCap devices are implicitly reduced according to the existing equation, and thus we do not see the need of the change at the moment. |
| CATT | No | Agree with the arguments above for ‘No’ |
| ZTE | No | In 38.306, the total layer 2 buffer size is defined as the sum of the number of bytes that the UE is capable of storing in the RLC transmission windows and RLC reception and reordering windows and also in PDCP reordering windows for all radio bearers.  In case other than MR-DC and NR-DC, it is calculated by:  *MaxDLDataRate \* RLC RTT + MaxULDataRate \* RLC RTT*  We think this requirement can be reused for RedCap.  Because peak downlink/uplink data rate is reduced compared to legacy UE, the total layer 2 buffer size requirement is reduced correspondingly. Thus it seems there is no spec impact. |
| OPPO | No | Agree with Huawei that with formula in TS 38.306, the required L2 buffer for RedCap Ues has been reduced, due to reduced bandwidth. This can be taken as baseline, and whether to further reduce on top of this can be FFS. |
| Sequans | Yes, but | We understand this to mean reduced compared to the calculation given by 38.306. We are open to this option in principle, but a lot of details are still open, e.g. the PHY parameters’ values and how to reduce (e.g. factor to data rate or RLC RTT) |
| DENSO | FFS | Given that CA/DC, MIMO and higher modulation order are not supported, the required L2 buffer size is anyway be reduced as defined in the spec below.  *MaxDLDataRate \* RLC RTT + MaxULDataRate \* RLC RTT*.  We’re open to discuss if further reduction is needed in the WI phase. |
| Xiaomi | No | Agree with the arguments above for ‘No’ |
| LGE | No | Same view with Huawei and MediaTek |
| Lenovo | Yes, but | But it needs to wait the further details in physical layer complexity reduction techniques as mentioned above. |
| Intel | No | We agree with Huawei and Mediatek. The L2 buffer size will be reduced implicitly if corresponding features are reduced. |

**Summary:**

19 companies provided comments on reducing total layer-2 buffer size for RedCap UEs compared with the value required by Section 4.1.4 in TS 38.306:

* 11 companies explicitly said NO. The main argument is that according to the formula in TS 38.306, with peak data rate reductions for RedCap UEs, L2 buffer requirements are implicitly reduced accordingly.
* 3 companies agree to reduce the buffer size but think it will automatically be achieved by reduction of peak data rate thus there is no specification impact.
* 4 companies are OK to discuss in WI when details about physical layer complexity reduction techniques re known.
* 1 company proposes to signal as a fraction of the theoretical value.

Considering that there is no enough support (only two companies) to reduce total layer-2 buffer size for RedCap UEs compared with the value required by Section 4.1.4 in TS 38.306, it is proposed not to reduce total layer-2 buffer size compared to the legacy calculation specified in TS 38.306.

**Proposal 2: Reduction of total layer-2 buffer size compared to the legacy calculation specified in TS 38.306 for RedCap UEs is not supported.**

**Question 1c.** Do you support to make support of 18-bit sequence number field for PDCP and RLC AM optional for RedCap Ues?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | With no CA/DC, 18-bit is not necessary |
| Qualcomm | Yes | 18-bit SN is needed only by high data rate applications. The longer the SN is, the bigger buffer UE needs to have to support the sliding window operations in PDCP/RLC. Since RedCap Ues are not expected to have high data rates (e.g. no CA or DC), 18-bit SN field becomes unnecessary. RedCap can use the 12-bit SN instead (currently optional for R15/16). |
| Ericsson | TBD | We agree that the whole 18-bit space is not needed but wonder what would the actual gain be?  We would like to avoid any changes to RLC and PDCP due to RedCap, but as brought up by QC this should be doable without changes to the existing specifications. |
| Huawei, Hisilicon | Yes | Considering that the required peak data rate for RedCap Ues is lower, 18-bit SN is not needed for RedCap UE. We can consider 12-bit SN as mandatory capability. |
| MediaTek | No | Agree with Ericsson that while the whole 18-bit SN space may not be used for RedCap operation, we do not see a significant gain associated with removing this option. Where possible, we should avoid changes to the NR baseline unless absolutely necessary. |
| Nokia, Nokia Shanghai Bell | TBD | While the whole space is not required for 18-bit SN, we don’t see it would contribute too much to RedCap UE complexity. However, this can be discussed further. |
| Futurewei | Yes | 12-bit SN can be considered as mandatory instead. |
| Sierra Wireless | Yes | Agree with Huawei |
| vivo | Yes with comments | We agree that RedCap Ues may not need 18 bits SN due to less use cases. But we need to first identify how much impact on the cost of the devices for this SN number. After that, we could discuss what is the exact number should be supported for RedCap Ues. |
| Samsung | TBD | We tend to agree that 18-bit SN may not be required, but at the moment, do not see a significant gain either. RAN2 can discuss it later. |
| CATT | No strong view | With the reductions that have already been taken into account (antenna, BW, DRB, power saving etc.) we should be able to achieve sufficient reduction that is possible in this release. We are not very sure about the changes to PDCH/RLC. We haven’t discussed much on this topic so this can be left out. |
| ZTE | TBD | The gain is unclear for us. We understand the buffer for sliding window is part of total L2-buffer which will be reduced according to question 1b. Will reducing SN space size further reduce buffer requirement? |
| OPPO | Yes | 12-bit SN can be considered as mandatory capability. |
| Sequans | Yes | Making 12-bit SN mandatory while making 18-bit SN optional sounds like a good fit for the mostly low data rates supported for REDCAP |
| DENSO | Yes | 18-bit sequence number space is not required for the target data rate supported by the RedCap Ues. |
| Xiaomi | No strong view | We doubt the significant gain and do not want to impact RLC/PDCP. |
| LGE | TBD | Agree with other companies. We can discuss this in the WI phase. |
| Lenovo | TBD | We hope it will not have impact to legacy specification. |
| Intel | TBD | 18 bits SN is not needed for RedCap UE. But additional gain by removing this should be studied. |

**Summary:**

20 companies provided comments on making support of 18-bit sequence number field for PDCP and RLC AM optional for RedCap UEs:

Most companies agree that 18-bit SN are not needed for RedCap UEs:

* 9 companies agree to make support of 18-bit sequence number field for PDCP and RLC AM optional for RedCap UEs.
* 11 companies said ‘TBD’/‘NO’/’No strong view’ as they think the gain is not clear enough.

Based on companies’ comments, most companies agree that 18-bit SN may not be required for RedCap UEs but 11 companies are not sure about the gain to make 18-bits SN optional. Thus it is proposed to capture 18-bit SN in the TR as one L2 capability which is possible to be reduced for RedCap UEs if benefit is identified.

**Proposal 3: Capture ‘18-bit SN for PDCP and RLC AM’ in the TR as one L2 capability which can be reduced for RedCap UEs if clear benefit is identified.**

**Question 1d.** Do you support relaxing the RRC processing delay for RedCap Ues?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | We need to discuss the details but we agree with increased processing times. |
| Qualcomm | Yes | NR reduced RRC processing time (compared to LTE) to better support low latency applications such as URLLC. However, most RedCap use cases do not have low latency requirement. Reducing RRC processing time do not have much impact on Ues’ control-plane performance but can relax their requirement on processor.  This relaxation can be signaled as a scaling factor (e.g. 1.25x) on top of R15’s mandatory RRC processing time, via UE capability signaling. |
| Ericsson | No | Not until we have discussed more details regarding this and whether there would be notable complexity gains. Also, we do not think latency should be increased from what it is now. |
| Huawei, HiSilicon | No | The relaxation of RRC processing delay will lead to longer RRC configuration fuzzy time, which is not beneficial for the resource scheduling efficiency of the network. Moreover, the necessity to relax processing time is not clear, and the advantage on the cost saving arising from relaxed RRC processing delay seems trivial compared to other capability reductions.  Note that if relaxation of RRC processing delay is allowed, identifying RedCap UE before Msg 4 is necessary because RedCap UE and non-RedCap UE have different processing time on Msg4. |
| MediaTek | No | Agree with Huawei that the cost savings associated with relaxing the RRC processing delay are expected to be trivial. We prefer to avoid changes to the NR baseline unless absolutely necessary. |
| Nokia, Nokia Shanghai Bell | No | Agree with Ericsson and Huawei. |
| Futurewei | No | There’d be larger impact on network than potential saving on UE. |
| Sierra Wireless | Yes | From UE power consumption perspective, this may have some value. It would probably need to be signalled early as a capability, to enable the network to accommodate the delay. |
| Vivo | No | As far as I know, RAN1 have made some quantified analysis on the PHY processing time, but there is no consensus on the cost reduction. Here, we also have the doubt for the impact on the cost.  Besides, we donot see much motivation to relax the RRC processing delay. |
| Samsung | - | We thought that ‘relaxed UE processing time/capability’ stated in the SID implies support of ‘relaxed RRC processing delay’, but we are also fine *not* to consider it to avoid fragmentation. |
| CATT | No | Gains seems to be limited. |
| ZTE | See comments | We share similar view as Ericsson and Huawei. It is unclear how much gain in cost reduction can be achieved by this relaxation.  Note that for RedCap UE, the message size of RRC message will smaller (and relatively simple) because CA/DC and other advanced features are not supported. The required processing time should already be reduced accordingly. |
| OPPO | FFS | This can be further discussed in the WI phase. |
| Sequans | Yes | Agree this should be studied, as this could allow less powerful CPU. Should not be reduced below LTE requirements. |
| DENSO | No | It is not certain whether URLLC functionalities are required even for the target data rate and the use cases for RedCap Ues. Agree with Ericsson that more details need to be discussed in the WI phase. |
| Xiaomi | No strong view | We doubt the significant gain. RAN1 has PHY processing time evaluation and the gain is marginal. |
| LGE | No | Same comment as MediaTek |
| Lenovo | No | We don’t see the significant necessity to relaxing the RRC processing delay for RedCap Ues. |
| Intel | No | Agree with Ericsson and Huawei. |
| Facebook | No |  |

**Summary:**

20 companies provided comments on relaxing the RRC processing delay for RedCap UEs:

* 4 companies support to relax RRC processing delay for RedCap UEs.
* 14 companies cannot see clear benefit. 1 company is fine not to relax RRC processing delay to avoid fragmentation.
* 1 company thinks this can be further discussed in WI phase.

Considering that there is no enough support (4 out of 20) to relax RRC processing delay for RedCap UEs, it is proposed not to reduce RRC processing delay for RedCap UEs.

**Proposal 4: RRC processing delay for RedCap UEs is not relaxed.**

## Impacts on procedures for RedCap UEs

In RAN2#111e meeting, the following agreement was made for the impacts on procedures for RedCap UEs:

Depending on RAN1 input, discussion is expected at least on the following impacts on RAN2 procedures:

a. Impact on cell (re)selection

b. Impact on initial access

c. Impact on other idle mode procedures (i.e. SI acquisition, paging)

In above contributions, the following observations on procedural impacts were made and it was proposed to capture them in the TR:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2101255 | Huawei, HiSilicon | Observation 1: RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection.  Observation 2: If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.  Observation 3: RedCap UE needs measurement GAP for serving cell measurement with higher probability than non-RedCap UE.  Proposal 3: Capture above observations into the TR. |

**Observation 1: RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection.**

**Question 2a. Do you agree with observation 1?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | yes | With reduced Rx/tx, more effort might be needed by redcap UEs to read broadcast info. |
| Qualcomm | Yes |  |
| Ericsson |  | This doesn’t need to be always true. The observation sounds more like something to be discussed in RAN1/RAN4 and not directly related to impact on RAN2 procedures.  Regarding P3 in R2-2101255, the original intention of the agreement seems to be to capture the possible impact on RAN2 procedures and not the possible impact on the lower layer procedures which may (or may not) impact the UE power consumption. Thus, we think it would be more appropriate for RAN1/RAN4 to come up with such concerns backed with analysis. Thus, we don’t think the observations are needed to be captured in the TR. |
| Huawei, HiSilicon | Yes | Agree with Apple.  Besides, RedCap UE may select or reselect to a cell which does not support RedCap UE, which consumes additional energy. We think cell selection/reselection is RAN2 scope thus we need to capture potential impact if identified.  We also agree with Ericsson that the observation only applies to some cases. |
| MediaTek | It depends on the WI discussion | The reasons provided in R2-2101255 for increased power consumption is due to the RedCap UE reselecting cells that may not support RedCap operation, requiring further cell search and reselection procedures to take place.  However we have briefly discussed indications of RedCap support in relation with reselection and agreed to postpone this discussion to the WI phase (R2-2009936). We can discuss this topic alongside the expected discussion in the WI phase. |
| Nokia, Nokia Shanghai Bell |  | We are not sure how this observation would impact RAN2 procedures. |
| Futurewei | Yes | It “may” happen. |
| Sierra Wireless | Yes | It is true to say “may” but it does not have to be so. Indirectly this could affect RAN2 if it means accommodating more delay. |
| vivo |  | We agree “may consume more power”. But we wonder what is the impact on RAN2 here. Our understanding is that, we could keep this observation in mind, and further discuss any potential impact in WI phase based on contributions. |
| Samsung | - | Same view as MediaTek. |
| CATT | yes it may |  |
| ZTE | Yes with changes | In an area that not all cell support RedCap access, RedCap UE may (re)select a cell not support RedCap access. Then more power is consumed for unnecessary measurement and MIB/SIB1reading.  As indicated by Ericsson, it may be discussed in RAN1/RAN4. However, it can also be discussed from RAN2 point of view. For example, indicating whether a neighbor frequency/cell support RedCap access to avoid unnecessary measurement.  Thus we agree to capture this into the TR with following changes:  **RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection, e.g. due to not aware of whether a neighbor frequency/cell support RedCap access.** |
| OPPO |  | Also not sure about the impact to RAN2 procedures. This can be further discussed in the WI phase. |
| Sequans | Yes | Both reading the broadcast information and reselecting to non-supporting cells could result in higher power consumption compared to regular UEs. Agree with SW |
| DENSO | Yes, but | It is true, if not all of the cells allow access from RedCap UEs. On the other hand, we incline to the view from Ericsson that the observations do not have to be captured in the TR, unless the potential solutions to address these issues are described. As commented to the following questions, these are more relevant to power saving enhancements. |
| Xiaomi |  | Same view as MediaTek. Further cell search and reselection procedures can be studied in the WI phase. |
| LGE |  | Probably, but same view with Ericsson. |
| Lenovo | - | Same view as Media Tek. |
| Intel |  | The details can be discussed in WI phase. |
| Facebook |  | Same view as MediaTek |

**Summary:**

20 companies provided comments on the observation that RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection.

* 9 companies agree with the observation.
* 11 companies think the procedure impact (e.g. on cell search and reselection) can be discussed in WI phase if identified.

Based on companies’ comments, there is no majority support to capture the observation that RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection. But it seem common understanding that potential impact on cell search and cell re-selection can be discussed in WI phase, if identified. Thus no proposal is made on this observation.

**Observation 2: If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.**

**Question 2b. Do you agree with observation 2?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes |  |
| Qualcomm | Yes | This issue is not necessarily specific to RedCap. The paging enhancements discussed in R17 Power saving are applicable to RedCap too. |
| Ericsson | Maybe with changes | This would mainly concern RedCap UEs which are in bad reception conditions. Without further analysis (e.g. link budget) it is not clear how significant this concern is in practice. |
| Huawei, HiSilicon | Yes | Agree with Qualcomm. Frequent paging of non-RedCap UEs will impact RedCap UEs regardless the reception conditions. But the impact on RedCap UEs that are in bad reception conditions will be larger. |
| MediaTek | Depends on NW implementation | Agree with Qualcomm that this is not a RedCap specific issue. POs are a function of the network assigned UE\_ID, and we expect that PO sharing and load management can be controlled by NW implementation. |
| Nokia, Nokia Shanghai Bell | Maybe | The impact would similarly exist for non-RedCap UEs. |
| Futurewei | Yes | This is a downside of sharing PO. |
| Sierra Wireless | Yes |  |
| vivo |  | We agree with Qualcomm that this is not RedCap specific issue, and this could be considered in R17 PowerSaving WI. |
| Samsung | Yes but | We have same view with as Qualcomm that the issue is discussing in R17 power saving. |
| CATT | yes it may |  |
| ZTE | See comments | False alarm probability is related to UE number and PO density. Thus it is hard to say whether the probability is impacted merely because PO is shared for RedCap and non-RedCap.  Another relative factor is paging probability. It is also unclear non-RedCap UE has higher paging probability than RedCap UE and vise versa.  For SIB1 reading issue, there is no agreement on which SIBs are not interested by RedCap UEs. Note that not all legacy UE are interested in all SIBs, so this is not Redcap specific issue too.  After all, we agree with Qualcomm that this issue is discussed in power saving. The outcome should be applicable for RedCap UE. |
| OPPO |  | This is not a RedCap-specific issue. It applies to all UEs. |
| Sequans | Yes | Agree that this is a general issue resulting from sharing POs and that the grouping enhancements discussed in R17 PowSav should be helpful and applicable. |
| DENSO | Yes, but | Agree with Qualcomm and Ericsson. |
| Xiaomi | Depends on RAN1 | If RAN1 confirms Redcap UEs requires coverage recovery or repetition for paging PDCCH/PDSCH transmissions, RAN2 is suggested to further discuss whether separate paging messages are needed. We can reuse the Sub-grouping method for different types of UEs which is now discussed in R17 UE power saving for this. |
| LGE | Yes |  |
| Lenovo | Yes | The RedCap UEs are critical to power consumption, the false probability and unnecessary SIB1 reading needs to be considered. |
| Intel | Maybe | The issue also exists for non-RedCap UE. Need to understand whether the issue is serious for RedCap UE or not. In addition, as pointed by Qualcomm, Any paging enhancements in Rel17 PWS will also reduce false probability for non-RedCap UE |
| Facebook | Yes |  |

**Summary:**

20 companies provided comments on the observation that If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.

No negative comment on the observation is received

* 12 companies indicate Yes explicitly and agree to capture the observation to the TR.
* 11 companies point out that the issue is not only for RedCap UEs
  + 9 companies think that the paging enhancements discussed in R17 Power saving should be applicable to RedCap too.
* 1 company thinks it depends on RAN1

Based on companies’ comments, it seems no objection on the observation but most companies think that the observation is not only for RedCap UEs, thus the paging enhancements discussed in R17 Power saving are applicable to RedCap too.

**Proposal 5: Capture in the TR that paging false alarm is not a specific issue for RedCap UEs. The paging enhancements discussed in R17 Power saving are applicable to RedCap also.**

**Observation 3: RedCap UE needs measurement GAP for serving cell measurement with higher probability than non-RedCap UE.**

**Question 2c. Do you agree with observation 3?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | 1Tx/1Rx results in this for eg. |
| Qualcomm | Yes |  |
| Ericsson |  | Again, without analysis / link budget results it is hard to assess the full situation, but this is likely true. Again, this sounds more like a RAN4 discussion topic. |
| Huawei, HiSilicon | Yes | Due to the limited bandwidth of RedCap UE, it is difficult to configure the active BWP of all RedCap UEs covering CD-SSB since it will degrade network performance to centralize too many RedCap UE working near CD-SSB. |
| MediaTek | Potentially yes | Limited RedCap bandwidth may result in a higher need for measurement gaps to measure the CD-SSB, when the network is trying to avoid crowding in the BW around the CD-SSB. However, agree with Ericsson that this is more of a RAN4 discussion. |
| Nokia, Nokia Shanghai Bell |  | Agree with Ericsson |
| Futurewei | Yes | This may be caused by reduced BW and UE Rx capability. |
| Sierra Wireless | Yes |  |
| vivo |  | Based on the limited conclusions for RedCap UEs, we are not sure whether it is true. This needs some quantified analysis in RAN4. |
| Samsung | - | Agree with Ericsson |
| CATT | yes it may |  |
| ZTE |  | Similar view as Ericsson. This issue should be discussed in RAN4 first. |
| OPPO |  | Agree with Ericsson that this should be discussed in RAN4. |
| Sequans | Probably Yes | Agree with MediaTek |
| DENSO |  | Agree with Ericsson. From the realm of RAN2, it cannot be assessed whether the gap is needed for RedCap UEs or not. RAN4 can discuss and conclude the necessity. |
| Xiaomi |  | It should be discussed in RAN4. |
| LGE |  | Agree with Ericsson |
| Lenovo |  | Not sure about this, it is more like a RAN4 issue. |
| Intel |  | It should be discussed in RAN1/RAN4 first on:  1 whether the 100M network may configure CD-SSB and active BWP in different frequency location in order to avoid the congestion.  2 what gap requirement will be. |

**Summary:**

19 companies provided comments on the observation that If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.

No negative comment on the observation is received

* 8 companies indicate Yes explicitly and agree to capture the observation to the TR.
* 13 companies think that the observation should be discussed in RAN4

Based on companies’ comments, there is no majority support to capture the observation in the TR. Thus no proposal is made on this observation.

## One v.s. multiple RedCap UE type(s) (Pros/Cons)

Regarding how many type(s) should be defined for RedCap UEs, proposals from above contributions are listed below:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2100310 | Qualcomm Incorporated | Proposal 1. Only a single RedCap UE type (per FR) is defined. |
| R2-2100460 | vivo, Guangdong Genius | Proposal 1: Two UE types/categories should be defined for RedCap devices to cover various use cases: high-end and low-end devices.  Proposal 2: Two UE types/categories for RedCap devices can be defined based on the UE features (e.g. Bandwidth, antenna number, etc.). Detailed reduced capability could be discussed and decided in WI. |

The number of RedCap UE type(s) has been discussed in the previous RAN2 meetings and the following principle has been agreed in RAN2#111e:

1. 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

The discussion here is not for down-selection but for elaborating pros/cons for both options, i.e. only one UE type v.s. multiple UE types.

**Question 3.** Companies are invited to provide comments on pros/cons to have only one v.s. multiple RedCap UE type(s).

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Only one RedCap UE type*** | ***Multiple RedCap UE types*** |
|  | * Pros: * Cons: | * Pros: * Cons: |
| Apple | We prefer to not fragment. Anyway the capabilities would be exchanged to know the different “types” of RedCap, and for initial access, all RedCapUEs are required to support a min BW. We do not see the need to define more types. Also, RAN1 is also discussing this, and their input needs to be considered. |  |
| Qualcomm | For access, we think a single UE type is sufficient for network to enforce access restriction (ensure RedCap is used only for its intended use cases). Once UE is connected, network can learn different capability levels of RedCap UEs from capability signaling.  Have a single UE type is simple, avoid market segmentation. Although a single UE type is defined, one can still potentially support an infinite number of feature permutations in the market, through NR’s capability framework. | Defining multiple UE types means that 3GPP would have to take on the role of product management and identify specific product segments to determine where to draw the line between different UE types. In our view, that’s outside 3GPP’s scope. |
| Ericsson | We would like to note that “RedCap UE type” has not been defined yet so it is strange to discuss number of RedCap UE types before the definition is clarified.  Pros:   * No fragmentation of “types” * Simpler specification-wise * Re-uses existing functionality (e.g. capability signaling) * Not going back to “UE categories” like in LTE. | Pros:   * More fine-grained control from NW side potentially possible   Cons:   * It is not straightforward to map use cases to “UE types”. * Requires more changes to specifications. * Results in more resource use (e.g. PRACH resources, Mgs3 bits) * Effectively bringing back “UE categories” from LTE which were deliberately avoided in NR.   Agree with QC on the discussion going out of 3GPP scope. |
| Huawei, HiSilicon | Pros:   * Avoid market fragmentation. * Only one type is enough for the network to control the access of RedCap UEs. Redcap UEs can still report different capabilities for different use cases. * Simpler specification, e.g. easy early identification   Cons:  No obvious cons is observed | Pros:  No clear pros is observed.  Cons:   * Market fragmentation, which has been agreed to be avoided * Early identification will be complex. * Larger spec impact to define access restriction and identify capabilities/features supported for each type. * Agree with QC and Ericsson that defining multiple device types are out of 3GPP scope. |
| MediaTek | Pros:   * Avoids market fragmentation * Simple specification * Easy early identification   Cons:   * No obvious issues identified | Pros:   * No obvious advantages identified   Cons:   * Market fragmentation * Complex early identification * Specification complexity   The criteria we have agreed on to define a device type are:   * to control UE access * to differentiate from legacy (eMBB) UEs.   We see no reason to justify defining more than one RedCap UE based on the criteria we’ve agreed upon. |
| Nokia, Nokia Shanghai Bell | Agree with above. |  |
| Futurewei | Agree with above comments. | Agree with above comments. |
| Sierra Wireless | There may be many different sets of capabilities for RedCap devices. Reporting one type implies treating all as the least capable. More capability information should be reported by the UE before potentially barring all. | There may be value to having at least two types based on distinguishing the most limiting capabilities, e.g. 1Rx and 2Rx. Other capabilities still need to be reported. |
| vivo | Pros:   * No obvious advantages identified   Cons:   * it will be challenging to achieve the targets on data rate/power efficiency for different use cases, e.g. sensor/low-end wearable vs. video surveillances * The capabilities set cannot be differentiated by use cases * Vast of low end sensors will impacts on the performance of high end devices | Pros:   * It is hard to define a common set of capabilities for different use cases. * Good for NW to control/offload different types of RedCap UEs * Good to meet the requirements for various use cases * Optimize the tradeoff between the economics of scale and cost/power efficiency   Cons:   * No obvious issues identified |
| Samsung | Just to give rapporteur a short answer, we prefer to have a single type to avoid market fragmentation. | - |
| CATT | Ericsson has the point that redcap type has not been clearly defined yet. Currently R1/2 only provide a set of possibilities of how redcap type is defined.  Besides what have been stated by companies, i.e., we should also take into account the futureproofness of this design. For example, of we are going to introduce a type new in R18, the R17 framework needs to be futureproof. | See comments on the left |
| ZTE | How to define RedCap UE type is not determined and there are several options on the definition method. However,we can discuss the impact of type numbers from RAN2 point of view.  Pros:   * avoid market fragmentation. * More flexible for vendors and future proof. The device type can be defined with a set of minimal requirement for all RedCap UE. Vendors can implement optional capabilities according to its target market requirements. * less specification effort and network implementation complexity (e.g. NW capability indication and UAC). * less resource fragmentation for UE type identification. | Multiple UE types enable more fine-grained in access control. But the benefit seems not necessary.  Cons:   * It is improper to define product spec in 3GPP specification.Vendors can design high-end device based on minimal requirement for all RedCap UE with additional more advanced capabilities. * limits the flexibility in product design and not future proof. * complexity in NW capability indication and UAC and specification effort. * more resource fragmentation for type identification |
| OPPO | Agree with above. |  |
| Spreadtrum |  | Two UE types are needed.  It may be too late to feedback during capability report for some capabilities, e.g. 1Rx and 2Rx, which can be potentially used for coverage improvement by large PDCCH AL or low TBS scaling etc. without spec impact. For the concern of market segmentation, we think low-end and high-end RedCap device can be used to match different market demand like LTE Cat 4 and 1bis, which has been proved by the fact of current deployment. In fact, in our view, market segmentation for RedCap UE has been there, since 1Rx and 2Rx have been supported for some FDD bands. |
| Sequans | We prefer this option.  The only benefit of having more than one type compared to the already existing NR capabilities scheme is having some differentiation during initial access; In our view, one REDCAP type is enough for this purpose, and more advanced capabilities can be reported.  This also avoids al the cons of having multiple types | Cons:   * fragmented market * requires market/non-technical considerations * more complex * additional fragmentation of resources |
| DENSO | Agree with Apple, Qualcomm and Ericsson. It should be noted that eMTC and NB-IoT defined a single type of UE specification wise, even though they have been used for various type of services in the real market. The similar consequence would be envisaged for Redcap UEs in reality. | Agree with Qualcomm and Ericsson that multiple UE types for different usage is outside 3GPP’s scope. |
| Xiaomi | It is desirable that all the Redcap UEs can have a unified initial access scheme if the network can schedule the UE based on the least capable Redcap UE. In this way, a single UE type is sufficient for initial access.  And finer Redcap UEs can be reported to the network afterwards on what it supports beyond this set of minimum capabilities. At least two RedCap device types providing different peak data rate should be supported to adapt different use cases, e.g., 40MHz and 1 Rx and 20MHz and 2Rx. |  |
| LGE | Cons:  It may not be easy to provide optimized configurations depending on the different types of use cases (i.e. Wearables and IWSN) | Pros:   * More fine-grained control.   We are wondering how many RedCap device types would be appropriate to avoid market fragmentation. For example, one RedCap device type is ok but two is not? |
| Lenovo | Pros:   * Less fragmentation of UE types   Cons:   * Less flexible on network-controlled access * Less resource usage efficiency on data transmission | Pros:   * More flexible access control, e.g. restriction of UEs with "low capabilities" if needed * More efficient resource usage, e.g., better Msg2/3/4 link adaptation based on UE capability.   Cons:   * More fragmentation caused by multiple UE types. However, this might be tolerable with 2 UE types. |
| Intel | Agree with above. | Agree with above. |
| Facebook | Agree with the pros and cons  But the number of types should be TBD when we have a better consensus on the use cases | Agree with the pros and cons  But the number of types should be TBD when we have a better consensus on the use cases |

**Summary:**

21 companies provided comments on pros/cons to have only one v.s. multiple RedCap UE type(s). The comments are summarised in the table below:

|  |
| --- |
| **Market fragmentation**  11 companies think that defining only one RedCap type can avoid market fragmentation.  2 companies think 2 types might be tolerable from market fragmentation perspective.  **Observation**: No market fragmentation is pros to have only one RedCap UE type (cons to have multiple RedCap UE types) |
| **Access Control**  7 companies think that defining multiple RedCap type can provide finer flexibility for access control.  4 companies think that one RedCap type is enough from access restriction point of view.  **Observation**: More flexibility for access control/restriction is pros to have multiple RedCap UE types (cons to have only one RedCap UE type) |
| **Specification impact**  7 companies think that defining only RedCap type has smaller specification impact and make the specification simpler, e.g. on early identification, access control, etc.  No negative comment on this aspect is received.  **Observation**: Simpler specification, e.g. on early identification, access control, etc is pros to have only one RedCap UE type (cons to have multiple RedCap UE types) |
| **Product management/segments**  7 companies think that defining multiple UE types means that 3GPP would have to take on the role of product management and will lead to non-technical discussion, which is outside 3GPP’s scope.  1 company thinks that defining multiple UE types is beneficial for the tradeoff between the economics of scale and cost/power efficiency.  **Observation**: Leading to non-technical discussion outside 3GPP’s scope is cons to have multiple RedCap UE types. |
| **How to meet the requirements of different use cases**  3 companies think that it is hard to define a common set of capabilities for different use cases thus it is difficult to provide optimised configurations to meet the requirements for various use cases.  6 companies think that even if only one type is defined, for both the NW and the UE sides, it is still possible to implement optional capabilities according to different use cases.  **Observation: For this aspect, no clear pros/cons is identified for both options compared to each other.** |
| **Other aspects:**  There are also other aspects mentioned by companies, e.g., defining multiple device types is beneficial to distinguish UE with 1Rx/2Rx, or 20Mhz/40Mhz bandwidth. But this seems RAN1 scope, thus no observation is made on this aspect. |

Based on above observations in the table, the pros/cons for each option from RAN2 perspective is proposed as blew:

**Proposal 6: Capture the pros/cons to have only one v.s. multiple RedCap UE type(s) in the TR as below:**

**Only one RedCap UE type:**

**Pros:**

* No market fragmentation of “types”
* Simpler specification, e.g. on early identification, access control, etc.

**Cons:**

* Cannot provide independent access control for different UE types

**Multiple RedCap UE types:**

**Pros:**

* Flexible access control is possible if necessary, e.g. independent access control for different UE types

**Cons:**

* Potential market fragmentation of “types”
* More specification complexity/effort, e.g. on early identification, access control, etc.
* May lead to non-technical discussion outside 3GPP’s scope, e.g. product management

# Conclusion

This offline discussion focused on L2 capabilities and UE types for REDCAP:

*Proposal for agreement:*

**Proposal 1: Capture ‘maximum number of DRBs mandatory supported’ in the TR as one L2 capability which can be reduced for RedCap UEs. (17/20)**

**Proposal 4: RRC processing delay for RedCap UEs is not relaxed. (16/20)**

*Continue online discussion:*

**Proposal 2: Reduction of total layer-2 buffer size compared to the legacy calculation specified in TS 38.306 for RedCap UEs is not supported.**

**Proposal 3: Capture ‘18-bit SN for PDCP and RLC AM’ in the TR as one L2 capability which can be reduced for RedCap UEs if clear benefit is identified.**

**Proposal 5: Capture in the TR that paging false alarm is not a specific issue for RedCap UEs. The paging enhancements discussed in R17 Power saving are applicable to RedCap also.**

**Proposal 6: Capture the pros/cons to have only one v.s. multiple RedCap UE type(s) in the TR as below:**

**Only one RedCap UE type:**

**Pros:**

* No market fragmentation of “types”
* Simpler specification, e.g. on early identification, access control, etc.

**Cons:**

* Cannot provide independent access control for different UE types

**Multiple RedCap UE types:**

**Pros:**

* Flexible access control is possible if necessary, e.g. independent access control for different UE types

**Cons:**

* Potential market fragmentation of “types”
* More specification complexity/effort, e.g. on early identification, access control, etc.
* May lead to non-technical discussion outside 3GPP’s scope, e.g. product management

TP for above proposals are provided in section 5.

# Contact delegates

|  |  |  |
| --- | --- | --- |
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# Text Proposal for 38.875

==================================Start of 1st Change =================================

7.x Reduction of higher layers capabilities

7.x.1 Description of feature combinations

The reduction of the following higher layer capabilities have been studied:

- Maximum number of DRBs mandatory supported by RedCap UEs

- Total layer-2 buffer size

- 18-bit SN for PDCP and RLC AM

- RRC processing delay

In the study, reduction of the following higher layer capabilities can be considered to reduce UE cost and complexity:

**Maximum number of DRBs mandatory supported by RedCap UEs:**

Considering that the traffic types supported by RedCap UEs is less than non-RedCap UEs, the maximum number of DRBs mandatorily supported by RedCap UE should be reduced.

**18-bit SN for PDCP and RLC AM:**

Considering that the required peak data rate for RedCap UEs is lower than non-RedCap UEs, the whole 18-bit SN for PDCP and RLC AM not needed for RedCap UEs. Thus it is possible to make support of 18-bit SN for PDCP and RLC AM optional for RedCap UEs if benefit on UE cost and complexity is identified.

==================================Start of 2nd Change =================================

8 UE power saving features

8.1 Introduction to UE power saving features

The following UE power saving techniques have been studied:

- Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits

- Extended DRX for RRC Inactive and/or Idle

- RRM relaxation for stationary devices

- Paging false alarm

The outcomes of the studies of these techniques are captured in clauses 8.2 through 8.5, respectively, and summarized in clause 13.

==================================Start of 3rd Change =================================

8.4 Paging false alarm

8.4.1 Description of feature

If RedCap UEs share PO with non-RedCap UEs, the power consumption of RedCap UEs may be impacted because of paging false alarm and unnecessary SIB1 reading. This issue is not for RedCap UEs only and corresponding enhancement is already being discussed in R17 power saving WI. The paging enhancements discussed in R17power saving WI should be applicable to RedCap also.

==================================Start of 4th Change =================================

10 Definition and constraining of reduced capabilities

10.1 Definition of reduced capabilities

[Editor's Note: This structure of this clause may be modified as it is populated with text proposals from RAN2.]

At least for RedCap UE identification, explicit definition of RedCap UE type(s) is needed. Pending conclusions on the reduced complexity features (as described in clauses 7 and 12) and RedCap UE identification (as described in clause 11), the definition of the RedCap UE types can be based on one of:

- Option 1: All the reduced capabilities recommended at the end of the RedCap study

- Option 2: Only include the reduced capabilities that the network needs to know during initial access, if any.

- Option 3: All the recommended reduced capabilities as well as recommended power saving features

- Option 4: The corresponding minimum set of the reduced capabilities that one RedCap UE type shall mandatorily support

If early identification during initial access is supported, at least maximum supported UE bandwidth during initial access (20 MHz for FR1 and 100 MHz for FR2) is included in the set of L1 capabilities of the device type for RedCap early identification. Note that this does not preclude the case where the early indication only indicates whether it is a RedCap UE or which type of the RedCap UEs if multiple UE types are defined.

As a baseline, the existing UE capabilities framework is used to indicate the capabilities of RedCap UEs. As currently specified in Rel-16, the UE reports its radio access capabilities at least when the network requests the UE to do so.

The network should be able to control whether RedCap UEs can access the cell and differentiate them from other, non-RedCap UEs. The number of different UE types should be minimised to reduce market fragmentation, and UE types should be introduced only where essential to control UE accesses and differentiate them from other non-RedCap UEs.

The UE capabilities can be categorized as:

* Minimum mandatory capabilities that all RedCap UEs support, if identified.
* Optional capabilities, to be signalled explicitly.

For capability signalling of RedCap UEs, the following scenarios are possible, however feasibility, applicability of the cases and the final division to categories depend on the exact RedCap capabilities (to be defined):

* For the features that are mandatory for non-Redcap UEs:

- The Redcap UE mandatorily supports the feature with the same value;

- The Redcap UE mandatorily supports the feature, but with different value (e.g. bandwidth value);

- The Redcap UE optionally supports the feature;

- The Redcap UE does not support the feature at all.

* For the features that are optional for non-Redcap UEs:

- The Redcap UE does not support the feature at all.

- The Redcap UE supports the feature with a different value;

- The Redcap UE supports the feature with the same value;

- The Redcap UE mandatorily supports the feature

Based on the above categorization and possible scenarios, the following capability design principle alternatives can be considered:

Alternative 1:

- The UE capability requirements for a RedCap device type, that are different from those for non-RedCap UEs, are listed in the specifications. That is:

- Mandatory features for non-RedCap UEs that are not applicable for RedCap UEs.

- Mandatory features for non-RedCap UEs that are optional for RedCap UEs.

- Mandatory features for non-RedCap UEs that are supported for RedCap UEs but with different value.

- Optional features for non-RedCap UE that are not applicable for RedCap UE.

- Optional features for non-RedCap UE that are mandatorily supported for RedCap UE.

For a RedCap device type, define new signalling fields in UE capability signalling for the features that are mandatory without capability signalling for non-RedCap UEs but are optional for Redcap UEs, or mandatory with capability signalling for non-RedCap UEs but with different value for RedCap UEs. Such new signalling is only applicable for RedCap UEs.

Alternative 2:

- Directly define the UE capabilities required for RedCap devices, including:

- Mandatory features for RedCap UEs (defined in specification).

- Optional features for Redcap UEs (introduce signalling fields in an independent container defined specifically for Redcap UE).

The network should know whether the UE is a RedCap UE or not in order to handle UE capabilities properly (see also Section 11.1 on UE identification). The following options, which do not need to be mutually exclusive, can be considered for further analysis and down-selection:

Option 1: RedCap device type is indicated as part of the capability signalling.

Option 2: Define a new IE specifically for RedCap UEs containing RedCap-specific capabilities. The IE is included in the signalling only by Redcap UEs.

Option 3: The network identifies RedCap UEs based on identification solution (see Section 11.1), e.g. during Msg1, Msg3, MsgA, etc, (pending RAN1 conclusion). The identification is forwarded it to target gNB during handover.

Option 4: The network identifies RedCap UE based on the reported capabilities, assuming the identification can be done through RedCap-specific capabilities not used by non-RedCap UEs.

Editor’s note: FFS further changes to above options and possible options which are not yet captured.

Editor’s note: The details and numbers of device types is FFS and discussion should be coordinated between RAN1/RAN2.

From RAN2 perspective, the pros and cons to define only one device types or multiple device types are:

**Only one RedCap UE type:**

**Pros:**

- No market fragmentation of “types”

- Simpler specification, e.g. on early identification, access control, etc.

**Cons:**

- Cannot provide independent access control for different UE types

**Multiple RedCap UE types:**

**Pros:**

- Flexible access control is possible if necessary, e.g. independent access control for different UE types

**Cons:**

- Potential market fragmentation of “types”

- More specification complexity/effort, e.g. on early identification, access control, etc.

- May lead to non-technical discussion outside 3GPP’s scope, e.g. product management