I3GPP TSG-RAN WG1 Meeting #109-e R1-22xxxxx

e-Meeting, 9th – 20th May 2022

**Agenda Item: 9.6.1**

**Title: FL summary #1 on potential solutions to further reduce RedCap UE complexity**

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# 1 Introduction

This feature lead (FL) summary (FLS) concerns the Rel-18 study item (SI) on further NR RedCap UE complexity reduction [1, 2, 3]. This Rel-18 study item was preceded by a Rel-17 study item [4, 5] and a Rel-17 work item [6, 7, 8].

This document summarizes contributions [9] – [35] submitted to agenda item 9.6.1 and relevant parts of contributions [36] – [49] submitted to 9.6.2 and 9.6.3 and captures this email discussion on reduced maximum UE bandwidth:

|  |
| --- |
| [109-e-R18-RedCap-02] Email discussion on further UE complexity reduction by May 20 – Johan (Ericsson)   * Check points: May 18 |

The section numbering in this document follows the draft TR skeleton in [3]. The issues in this document are tagged and color coded with High Priority or Medium Priority. The issues that are in the focus of this round of the discussion are furthermore tagged FL1.

Follow the naming convention in this example:

* *eRedCapComplexityFLS1-v000.docx*
* *eRedCapComplexityFLS1-v001-CompanyA.docx*
* *eRedCapComplexityFLS1-v002-CompanyA-CompanyB.docx*
* *eRedCapComplexityFLS1-v003-CompanyB-CompanyC.docx*

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

* Assume CompanyC wants to update *eRedCapComplexityFLS1-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *eRedCapComplexityFLS1-v003-CompanyB-CompanyC.checkout*
* CompanyC checks that no one else has created a checkout file simultaneously, and if there is a collision, CompanyC tries to coordinate with the company who made the other checkout (see, e.g., contact list below).
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In file names, please use the hyphen character (not the underline character) and include ‘v’ in front of the version number, as in the examples above and in line with the general recommendation (see slide 16 in [R1-2203012](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203012.zip)), otherwise the sorting of the files will be messed up (which can only be fixed by the RAN1 secretary).

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

**FL1 Question 1-1a: Please consider entering contact info below for the points of contact for this email discussion.**

|  |  |  |
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# 6 Evaluation methodology

6.1 Evaluation methodology for UE complexity reduction

According to the Rel-18 study item description (SID) on further NR RedCap UE complexity reduction [1], further UE complexity reduction techniques should be studied based on Rel-17 evaluation methodology in TR 38.875 [4].

Several contributions [9, 10, 11, 12, 13, 14, 19, 20, 21, 25, 27, 32, 38, 42] provide their views on the cost estimate methodology and present some initial results for Rel-18 enhanced RedCap (“eRedCap”). Regarding the cost estimation methodology, these contributions state that the detailed cost breakdown for the reference NR devices (as provided in Table 6.1-1 in TR 38.875 [4]) should be reused, where the RF-to-baseband cost ratio was assumed to be 40:60 for an FR1 UE. Also, [37] mentions that the selection of reference UE needs to be discussed for Rel-18 RedCap UE cost evaluation.

For cost saving evaluations compared to a Rel-17 baseline, contributions present their results with respect to different versions of Rel-17 RedCap UEs. For example, [10, 12, 14, 21, 39, 42] consider the simplest Rel-17 RedCap (with 20 MHz, 1 Rx, 1 layer, DL 64QAM, HD-FDD or TDD) as the baseline. In particular, the potential further UE complexity reduction features in Rel-18 are considered in combination with the mentioned simplest Rel-17 features [10, 36, 39]. One contribution [9] proposes to define a baseline Rel-17 RedCap UE that supports 20 MHz, 1 Rx, 1 layer, DL 64QAM without HD FDD.

* [9]: Define a baseline Rel-17 RedCap UE that supports a maximum 20 MHz bandwidth, one Rx branch, one MIMO layer, and a maximum DL modulation order of 64QAM.
* [10]: The potential gain of further complexity reduction in Rel-18 should be evaluated with respect to the simplest Rel-17 RedCap UEs.
* [21]: The results of the Rel-18 complexity reduction features are compared against a baseline Rel-17 RedCap UE (20 MHz) with 1Tx-1Rx, 64-QAM DL/ UL, HD-FDD or TDD.
* [36]: The cost evaluation for Rel-18 feature(s) should be carried out by comparing to the simplest Rel-17 RedCap.
  + Comparison of ‘all R17 RedCap features’ and ‘all Rel-17 RedCap features + Rel-18 feature(s)’.

Based on the views provided by contributions, the following questions can be considered regarding the evaluation methodology for Rel-18 UE complexity reduction.

**FL1 High Priority Question 6.1-1a: For cost reduction estimation, can the detailed cost breakdown for the Rel-15 reference NR devices (as provided in Table 6.1-1 in TR 38.875 [4]) be reused?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI1 | Y |  |
| Spreadtrum | Y |  |
| CMCC | Y | We think both of the following alternatives are OK.   * Alternative 1: reuse the same reference NR device as R17 RedCap UE. * Alternative 2: take R17 RedCap device as reference. |
| CATT | Y |  |
| vivo | Y |  |
| Sharp | Y |  |
| Qualcomm | Y |  |
| Transsion | Y |  |
| Nordic | Y, but | It should be possible to challenge companies numbers before included into average. In other words, the cost reductions estimates should be justified technically. |
| NEC | Y |  |
| ZTE, Sanechips | Y |  |
| Ericsson | Y |  |
| DOCOMO | Y, in general | As discussed in Question 6.1-3a, L2 buffer size reduction aspects can be studied additionally. |
| Samsung | Y | We suggest to use R-15 cost breakdown.  No need to spend time on analysis R17 Redcap UE breakdown, considering we only have two meeting in this SI, and there are many options for R17 Redcap UEs |
| IDCC | Y |  |

**FL1 High Priority Question 6.1-2a: For comparison with a Rel-17 baseline when evaluating the potential Rel-18 UE complexity reduction features, can the simplest Rel-17 RedCap (with 20 MHz, 1 Rx, 1 layer, DL 64QAM, HD-FDD or TDD) be considered as the baseline? If no, please provide your comments with your proposed baseline.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI |  | We support having a Rel-17 baseline when evaluating potential Rel-18 complexity features. In our baseline, we used (20 MHz, 1 Rx, 1 layer, DL 64QAM) while excluding HD-FDD.  In our view, HD-FDD is a limited use case with access restrictions. We should not make a decision about whether to support complexity technique based on HD-FDD, but we could support HD-FDD if a majority of companies want to include it as part of the baseline. |
| Sierra Wireless | Y | We agree with the proposed baseline. We do prefer to include HD-FDD as part of the baseline. |
| Spreadtrum | Y | Further question is: do we need to establish the detailed cost breakdown for the baseline (simplest Rel-17 RedCap)? After combine all the features (20 MHz, 1 Rx, 1 layer, DL 64QAM, HD-FDD or TDD), the rest cost of each component may need to be calibrated, e.g., take the average of all the values provided by companies. |
| Panasonic | Y |  |
| CMCC | Y | Take R17 RedCap with low end configuration as baseline is reasonable. |
| CATT |  | We think Rel-15 NR UE can still be a baseline. Nevertheless, we are open to reconsider defining a Rel-17 reference RedCap UE as the baseline.  Besides, to align TDD and FDD as much as possible, HD-FDD is not needed. Anyway, Type A HD-FDD is a common option feature to both Rel-17 RedCap and Rel-18 eRedCap in paired spectrum. For cost reduction, we should focus on the difference, rather than something common. |
| vivo | Y |  |
| Sharp |  | HD-FDD as a standalone feature is not available in many cases of R17-redcap UE. We don’t think HD-FDD shall be made as the sole baseline for FDD/eRedCap evaluation. |
| Qualcomm | Y |  |
| Transsion | Y | Take simplest Rel-17 RedCap(with 20 MHz, 1 Rx, 1 layer, DL 64QAM, FDD or TDD) as baseline is reasonable while excluding HD-FDD. Half duplex can be estimated separately as TR 38.875. |
| Nordic | N | Not sure why FD-FDD product cost could not be reduced as well in R18. We should indeed look at HD-FDD and FD-FDD and TDD separately. |
| NEC | Y |  |
| ZTE, Sanechips | Y |  |
| Ericsson | Y | We are also fine with having two sets of evaluation results, one for HD-FDD UEs and one for FD-FDD UEs, although we see a risk that the evaluation results will be less thorough if some companies only provide results for one of the cases.  Regarding Spreadtrum’s suggestion to establish a detailed cost breakdown for the simplest Rel-17 RedCap UE, we think that it can (and should) simply be included as one of the combinations to evaluate. (Ideally, it would have been good to agree on a common detailed cost breakdown for the simplest Rel-17 RedCap UE before carrying on with evaluation of the further complexity reduction techniques, but there does not seem to be enough time for such an additional step in the evaluation process due to the limited time for this study item.) |
| DOCOMO |  | We share the same view with CATT that Rel-15 NR UE can be the baseline, and hence it is necessary to discuss which UE of Rel-15 or Rel-17 RedCap can be the reference UE before we discuss the baseline for Rel-17 RedCap UE. |
| Samsung |  | We think HD-FDD shall not be the baseline.  FD-FDD and TDD shall be the baseline. |
| IDCC |  | We prefer FD-FDD and TDD. |

Furthermore, L2 buffer size reduction aspect is mentioned in [9, 12, 14]. In [9], it is argued that it may not be worthwhile to spend time re-discussing L2 buffer size in Rel-18 as it is difficult to estimate its complexity reduction at the physical layer. Contribution [14] states that clarification about L2 buffer size reduction for peak rate reduction is important. Contribution [36] proposes to consider the cost of memory (external to the RF and BB parts) in the study.

**FL1 High Priority Question 6.1-3a: Should the impact on memory size/cost/complexity (external to the RF and BB parts) be studied/evaluated/captured somehow? Please elaborate in the Comments field.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI1 | N | No changes are needed as the SID says the evaluation methodology is based on TR 38.875.  Even considering memory for the L2 buffer size will complicate the analysis:   * The ratio of RF complexity and baseband complexity may change (possibly in the reference model) – making comparisons to very difficult * The L2 buffer is also dependent on implementation, as the memory needed may be slower that the memory for HARQ * Because L2 memory is smaller since units are bits, not LLRs, the overall complexity for memory is smaller than for HARQ. |
| Sierra Wireless | N | Cost savings would be small. |
| Spreadtrum | Y | Rel-17 evaluation methodology is only focus on RF and BB, but the situation is there is no much room for cost reduction in RF and BB on top of R17 simplest RedCap.  However, BW reduction to 5MHz and reduced peak data rate are both lead to a lower peak data rate, which means lower L2 buffer size requirements. According to 38.306, if the peak data rate can be reduced from 80Mbps to 10Mbps, the L2 buffer size can be reduced by 87%. Further, lower peak data rate/L2 buffer size corresponding to lower memory requirements (e.g., model selection, from LPDDR to PSRAM), then the less cost of memory. At least from our perspective, the cost reduction for memory is significant, and it is another important motivation for R18 RedCap.  We understand that it is difficult and lack of time to establish an evaluation methodology for memory (external to the RF and BB parts), but we can **at least capture the information (e.g., the memory cost can be reduced by R18 features) in the TR** to convey correct and positive information to the vertical industries. |
| CMCC |  | We are open for such analysis if they do have non-negligible cost reduction gain, and if the performance impact and spec impact are small. |
| CATT |  | Open to consider. |
| vivo |  | We are open to study. |
| Sharp |  | Open |
| Qualcomm | N | It is clearly stated in SID that “Study further UE complexity reduction techniques based on Rel-17 evaluation methodology in TR 38.875”. In Rel-17, we have not evaluated additional memory cost which is external to RF/BB parts. Following the SID, we need to keep the same methodology for Rel-18 study. |
| Transsion |  | Open to discuss |
| Nordic | Y | Memory size and its cost and size should be clearly considered. And L2buffer size is not the only aspect, softbit memory should be considered as well.  It is not clear whether above is already reflected in HARQ buffer. |
| ZTE, Sanechips |  | We are open to consider. |
| Ericsson |  | We are open to capture impact on memory size/cost/complexity qualitatively, but it should not be included in the quantitative evaluation (since that would mean that the cost breakdown for the reference UE cannot be reused). |
| DOCOMO |  | Open to consider the complexity reduction on memory size. |
| Samsung |  | We are open to capture some analysis on memory as commented by Spreadtrum. |
| IDCC |  | We are open to consider. |

Beyond the cost/complexity reduction evaluations, many contributions provide their initial evaluations on the impacts of different potential complexity reduction features [9, 10, 11, 12, 14, 15, 16, 19, 23, 24, 29, 31, 32, 34, 35]. It seems to be a common understanding that for each potential further UE complexity reduction feature, the performance impacts, coexistence impacts, specification impacts need to be analyzed. Therefore, the following question can be considered.

**FL1 High Priority Question 6.1-4a: For each potential Rel-18 further UE complexity reduction feature, should the performance impacts, coexistence impacts, and specification impacts be evaluated as listed in the draft TR skeleton [3]?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI1 | Partial Y | The question should be formulated to be independent of the ongoing skeleton discussion. We are OK to include subsections for Performance impacts, Network and coexistence impacts, and Specification impacts, but not (for now) any particular structure within Performance impacts. |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| Panasonic | Y |  |
| CMCC | Y | This is what has been done during R17 SI. For the coexistence impacts, and specification impacts, evaluation if mainly based on analysis. While for performance impacts, evaluation can be based on either SLS/LLS evaluation or analysis. |
| CATT | Y in general | Some features have already been analyzed in Rel-17, e.g. relax processing time. For these features we can just quote Rel-17 TR for simplicity. |
| vivo | Y |  |
| Sharp | Y |  |
| Qualcomm | Y |  |
| Transsion | Y |  |
| Nordic | Y |  |
| NEC | Y |  |
| ZTE, Sanechips | Y | Since the baseline is R17 RedCap UE, some updates for relax processing time also are needed, e.g., the additional complexity reduction based on R17 RedCap UE, more description regarding CSI relaxing. |
| Ericsson | Y | We are fine with Futurewei’s name proposal “Network and coexistence impacts”. |
| DOCOMO | Y |  |
| Samsung | Y |  |
| IDCC | Y |  |

# 7 UE complexity reduction features

7.1 Introduction to UE complexity reduction features

According to the SID [1], some further complexity reduction enhancements may be considered to further expand the market for RedCap use cases with relatively low cost, low energy consumption, and low data rate requirements, e.g., industrial wireless sensor network use cases. Rel-18 eRedCap should provide NR support for low-tier devices between existing LPWA UEs and the capabilities of Rel-17 RedCap UEs. The supported peak data rate for Rel-18 eRedCap targets to 10 Mbps and Rel-18 eRedCap should not overlap with existing LPWA solutions.

Specifically, the objectives of this SID are as follows ‎[1]:

|  |
| --- |
| * Study further UE complexity reduction techniques based on Rel-17 evaluation methodology in TR 38.875 [RAN1]   + Consider network impact, coexistence of Rel-17 and Rel-18 RedCap and non-RedCap UEs in a cell, UE impact, specification impact   + Potential solutions, which may complement each other, for reducing device complexity are focusing on:     - UE bandwidth reduction to 5 MHz in FR1,       * Possibly in combination with relaxed UE processing timeline for PDSCH and/or PUSCH and/or CSI     - reduced UE peak data rate in FR1,       * Possibly including restricted bandwidth for PDSCH and/or PUSCH       * Possibly in combination with relaxed UE processing timeline for PDSCH and/or PUSCH and/or CSI * Notes:   + Rel-15 SSB should be reused and L1 changes minimized.   + Operation in BWP with/without SSB and without/with RF retuning should be considered.   + It is not precluded that some solutions for FR1 can be applied to FR2 in WI stage.   + Aim to define a single Rel-18 RedCap UE type for further UE complexity reduction. |

As we can see, the three main potential complexity reduction features are further UE bandwidth reduction, further UE peak rate reduction, and relaxed UE processing timeline. In the following, different aspects of each potential complexity reduction feature and their potential combinations are discussed.

7.2 Further UE bandwidth reduction

This section focuses on different UE bandwidth reduction options which need to be evaluated. In general, the UE bandwidth reduction can be applied to both radio frequency (RF) and baseband (BB) parts or only to BB parts, both data and control channel or only data channels, and DL and/or UL. Contributions discuss different options for further UE bandwidth reduction in FR1 which are summarized below.

* **Option BW1:** Both RF and BB bandwidths are 5 MHz for UL and DL [9, 10, 11, 12, 13, 14, 18, 24, 25, 32, 33, 35]
* **Option BW2:** 5 MHz BB bandwidth for data and control channels with 20 MHz RF bandwidth for UL and DL [14, 18, 32, 33]
* **Option BW3:** 5 MHz BB bandwidth only for data channels with 20 MHz RF bandwidth for UL and DL. The control channels and other reference signals are still allowed to use a BWP up to the 20 MHz maximum UE RF bandwidth [10, 18, 25, 24, 28, 32, 33, 35]
* **Option BW4:** Baseband bandwidths for data channels can be smaller than 5 MHz for further cost saving. For example, 3 MHz baseband bandwidth only for data channels with 20 MHz RF bandwidth for UL and DL [10]
* **Option BW5:** 20 MHz UE bandwidth in idle/inactive state but 5 MHz bandwidth in connected state [9, 20, 31]
* **Option BW6:** 5 MHz BB bandwidth only for data channels only for DL with 20 MHz RF bandwidth [25]
* **Option BW7:** Both RF and BB bandwidths are 5 MHz only for DL while the UL bandwidth is 20 MHz [9]
* **Option BW8:** No RF reduction but BB reduction for all channels except SSB [18]

Clearly, there can be various options for further UE bandwidth reduction which some of them can be similar (or highly correlated). For evaluations, it is beneficial to down-select the most attractive options. In this regard, the following question can be considered.

**FL1 High Priority Question 7.2-1a: Among the different options presented above for further UE bandwidth reduction in FR1, which option(s) should be studied?**

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| --- | --- | --- |
| **Company** | **Option(s)** | **Comments** |
| FUTUREWEI1 | At least BW1, BW3, BW5 | Given the number of options, it is necessary to downselect. But we are open to consider other options.  Note: BW5 is just a dedicated RRC configuration using a 5 MHz BWP (maximum) operating in 20 MHz. |
| Sierra Wireless | BW3, BW8 | In general we need support for 20MHz RF for SSB/CORESET. |
| Spreadtrum | Option BW3 and maybe BW6 | We also discussed option BW1 in our contribution [12], so we add [12] into the contribution list of option BW1.  While for option BW1, we observed the following: 1) Either great spec impacts or great limitations, 2) Performance is severely degraded, 3) Cost reduction is not significant compared to other solution (e.g., restricted BW for data). Therefore, we don’t think option BW1 is attractive.  From our perspective, we support 20MHz RF, and prefer to take option BW3 as the key option for the following study. In addition, we also think option BW6 is considerable. |
| Panasonic | BW1, BW2, BW3 |  |
| CMCC | 1st: BW3  2nd:BW2, BW1, BW5  3rd:others | Maybe companies are free to provide analysis for all the options, with performance impacts, coexistence impacts, and specification impacts. With limited inputs for some of the options, how to make conclusion needs to be discussed.  We have add [24] in BW1 since there is discussion on this option in our contribution. |
| CATT | BW1, BW3 | (1) We may need to further clarify that 5 MHz bandwidth is a centralized one.  (2) BW5 seems similar to BW3 in cost reduction, maybe the difference is power consumption in connected mode?  (3) BW8 seems similar to BW2. |
| vivo | Option BW1, Option BW2, Option BW3 | For Option BW4 of 3 MHz baseband bandwidth only for data channels, we do not think it is in the SI scope.  For Option BW5, if 20 MHz UE bandwidth needs to be supported in idle/inactive state, we do not think the cost can be reduced compared to Rel-17 RedCap UE.  Option BW6 is similar to Option BW3, we select Option BW3 with more interested companies.  For Option BW7, the motivation and cost saving are not clear compared to Option BW1.  Option BW8 is similar to Option BW2, we select Option BW2 with more interested companies. |
| Sharp | BW1,BW3,BW8 | BW1 may be included as the baseline for other bandwidth reduction schemes |
| Qualcomm | BW1, BW3 | We prefer to minimize the set of the options. |
| Transsion | BW1,BW3 | BW2 cannot resolve the CORESET#0 with SCS of 30KHz problem. If RF bandwidth is 20MHz, CORESET#0 occupied 20MHz is preferred. |
| Nordic | Do not agree with FL proposal | Above is not a complete list and further it is messy. We should consider structuring the discussion for RF and BB separately, something like this:   * RF reduced for both DL and UL, DL only, UL only * BB reduced   + All signals and channels are limited to 5MHz     - In RRC connected only     - Except SSB     - ….   + Data channels only are limited |
| NEC | BW1, BW3, |  |
| ZTE, Sanechips | BW1, BW3 | These options can be divided into 2 categories  **Cat1:** reducing complexity/cost of data and control channel, i.e., 1, 2, 7 ,8  **Cat2:** mainly reducing complexity/cost of data channel for peak date reduction, i.e., 3,4,5,6  For Cat 2 options, they should be further discussed in 7.3 as shown in yellow highlighted part. And among these options, option **BW3** should be prioritized, which is more aligned with the SID and RAN discussion.  For Cat 1 options, according to the SID as shown in blue highlighted part, at least UE bandwidth reduction to 5M, i.e.,option **BW1** should be selected.   * + Potential solutions, which may complement each other, for reducing device complexity are focusing on:     - UE bandwidth reduction to 5MHz in FR1,       * Possibly in combination with relaxed UE processing timeline for PDSCH and/or PUSCH and/or CSI     - reduced UE peak data rate in FR1,       * Possibly including restricted bandwidth for PDSCH and/or PUSCH       * Possibly in combination with relaxed UE processing timeline for PDSCH and/or PUSCH and/or CSI |
| Ericsson | BW1, BW3, BW4 | We think the main options are RF+BB and BB-only bandwidth reduction for data channels for both UL and DL.  Option BW4 is attractive as further cost saving can be achieved with BB-only BW reduction by allowing the BB bandwidth to be smaller than 5 MHz while satisfying the peak data rate target. For example, with 3 MHz BB bandwidth the 10 Mbps peak data rate can be achieved.  Other options are either similar to (BW1/BW3) or are not expected to provide significant benefits. |
| DOCOMO | BW1, BW2, BW3 | BW2 can solve the potential frequency diversity gain degradation issue which is expected for RF BW reduction (e.g., BW1), and hence we prefer to include this option to evaluate.  We also prefer to include BW3 to evaluate since it can solve some impacts which is expected for BW1 and/or BW2, e.g., SSB reception, MIB-configured CORESET#0 and/or PDCCH AL with 5MHz BB BW etc.  We don’t see the need to differentiate the BW restriction between idle/inactive mode and connected mode (i.e., BW5). We are not sure whether BW reduction only for connected mode can provide meaningful complexity reduction gain given that idle/inactive mode may be the dominant state considering the traffic pattern of eRedCap UEs.  In our understanding, the target max. peak data rate (10Mbps) should be applied to both DL and UL while it is not clearly stated in SID. Therefore, regarding BW6 and BW7, we don’t see the need to differentiate DL BW and UL BW so far, but we are open to consider such option. |
| Samsung | BW1 | Our originally thinking BW 3 is part of peak data rate reduction solution. |
| IDCC | BW1, BW2, BW3 |  |

It should be noted that bandwidth reduction naturally results in the peak data rate reduction. The peak data rate can be larger than 10 Mbps with 5 MHz UE bandwidth and high modulation orders (e.g., 64QAM) in FDD. However, in TDD 5 MHz UE bandwidth, the peak data rate for UL or DL can be less than 10 Mbps depending on the TDD pattern [10].

Moreover, there can be similarity between bandwidth reduction options and peak data rate reductions. For example, under certain conditions, the option of BB bandwidth reduction for data channels can resemble the option of peak data rate reduction by restriction of number of PRBs for PUSCH/PDSCH discussed in the next section. Here, following TR 36.888, these two options are treated separately, one in the bandwidth reduction section and the other one in the peak reduction section. Meanwhile, the differences between these two options (i.e., in terms of PRB allocation) can be further discussed.

7.3 Further UE peak rate reduction

This section focuses on different UE peak rate reduction options which need to be evaluated. Contributions discuss different options for further UE peak data rate reduction (considering the 10 Mbps peak rate target) which are summarized below.

* **Option PR1:** Relaxation of the constraint for peak data rate reduction [10, 12, 13, 23, 31, 32, 35]
* **Option PR2:** Restriction of maximum TBS for PDSCH and PUSCH [10, 11, 12, 13, 18, 21, 32, 33, 34]
* **Option PR3:** Restriction of maximum number of PRBs (or bandwidth) for PDSCH and PUSCH [10, 11, 12, 13, 19, 24, 32, 33, 34, 35]
* **Option PR4:** Reduction of scaling factor for peak data rate duction [12, 14]
* **Option PR5:** Relaxation of the maximum modulation order from 64QAM to 16QAM [14, 20, 30, 33]

Clearly, there can be various options for further peak data rate reduction which some of them can be similar (or highly correlated). For evaluations, it is beneficial to down-select the most attractive options. In this regard, the following question can be considered.

**FL1 High Priority Question 7.3-1a: Among the different options presented above for further UE peak data rate reduction, which option(s) should be studied?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Option(s)** | **Comments** |
| FUTUREWEI | PR5, PR6 | PR6 is not listed above but in this option, data and control are not in same slot   * PR1/PR4: Should not be studied. Already discussed in Rel-17 * PR2: Should not be studied. It will come naturally from other techniques. * PR3: Neutral. It will be similar to some BW reduction option)   (note to FL: typo for PR4: “duction” -> “reduction”) |
| Sierra Wireless | PR2 | Reducing TBS size gives the most flexibility. |
| Spreadtrum | Option PR1, PR2, PR3 | For Option PR4, we think it can be discussed together with option PR1, since a smaller scaling factor may corresponding to a relaxed constraint.  Notes: we also discussed option PR1 in our contribution [12]. |
| Panasonic | PR1, PR2, PR4 |  |
| CMCC | PR1,PR2,PR3,PR4 | We are open for the options, while PR5 is not preferred due to low spectrum efficiency. |
| CATT | PR2, PR4, [PR3], [PR1] | I addback our position which is missing in the summary.  For PR3, it is more or less related to bandwidth reduction. Whether PR3 is needed or not depends on whether ‘BB bandwidth reduction’ is already assumed or not.  PR1 may be naturally applied with PR4. Otherwise it is questionable whether PR4 can work. |
| vivo | Either Option PR1 or Option PR4,  Option PR2  Option PR5 | Option PR3 can be covered by BW reduction for data channel only.  We are fine with either Option PR1 or Option PR4 if down-selection is needed. |
| Sharp | PR3,PR5 | PR5: the limitation of 16QAM is sufficient to meet the peak rate of 10Mbps and can effectively reduce the complexity/cost of BB and RF. |
| Qualcomm | PR1, PR3 | We prefer to minimize the set of the options. |
| Nordic |  | The final solution can be combination of multiple.  PR1, PR4 and PR5 are interconnected as they tackle reduction of spectral efficiency per RE  In our opinion if PRBs are reduced, then those should be reduced for all signals and channels as part of BWP BW reduction. Otherwise, UE cannot reduce FFT and such post-FFT buffer. -> PR3 could be dropped since it is part of BW reduction discussion already  Again proposal should have been structured like   1. Reduce spectral efficiency per RE 2. Reduce PRB allocation (this is already part of BW reduction study) 3. Reduce max TBS size |
| NEC | PR1, PR2, |  |
| ZTE, Sanechips | PR3/BW3, [PR1/PR4] | Fro our understanding, option PR3 is similar with option BW3. only one of them need to be evaluated.  For PR1 and PR4, they are also similar, and only one of them is needed for evaluation.  For PR5, it may have the impacts on system capacity and spectrum efficiency, and it also brings marginal complexity reduction and impacts on RACH procedure. Therefore, it is not our preference.  Therefore, PR3 or BW3 is the baseline for evaluation and we are also open to consider PR1 or PR4(only one of them). |
| Ericsson | PR1, PR2, PR3 | With Option PR1, we do not see any need for Option PR4.  To our understanding, the main difference between PR3 and BW3 is that PR3 allows for non-contiguous/distributed allocation of the PRBs within the full RF BW (20 MHz), whereas BW3 only allows for allocation within 5 MHz BW. Therefore, for PR3, the UE may need to buffer the full RF BW for the slot that the UE is scheduled. For BW3, the UE needs to buffer the full RF BW only until the PDCCH is processed. So, there would be some differences in cost estimates for one or more of the BB blocks for PR3 and BW3. |
| DOCOMO | At least PR2, PR3, PR5 | We are also supportive to consider the relaxation of the constraint (PR1) and introduce new scaling factor (PR4) for peak data rate calculation which can possibly provide further BB processing complexity reduction. |
| Samsung | PR3 | We think this is same as BW 3.  In our understanding, as described in SI   * reduced UE peak data rate in FR1,   + Possibly including restricted bandwidth for PDSCH and/or PUSCH   Only restricted BW for PDSCH and/or PUSCH belong to this reduced UE peak data rate. We would like to focus on the BW restriction for PDSCH and/or PUSCH first. If time is allowed, we can be flexible to discuss others. |
| IDCC | PR1, PR2, PR3 |  |

7.4 Relaxed UE processing timeline

This section focuses on different relaxed UE processing timeline options which could be evaluated. Contributions discuss two options for relaxed UE processing timeline which are summarized below.

* **Option PT1:** Relaxation of UE processing time for PDSCH/PUSCH in terms of N1 and N2 [9, 10, 11, 12, 14, 15, 16, 18, 19, 20, 21, 23, 25, 26, 28, 30, 31, 32, 33, 35]
* **Option PT2:** Relaxation of UE processing time for CSI in terms of Z and Z’ [9, 10, 11, 12, 15, 18, 20, 23, 25, 30, 35]

As discussed in Rel-17 [4], there is potential cost reduction for relaxed UE processing timeline with option P1 and/or option P2. Meanwhile, the evaluations in [4] assume the relaxation factor of 2, i.e., doubling N1/N2 and Z/Z’. In this regard, the following questions can be considered.

**FL1 High Priority Question 7.4-1a: Which option(s) should be studied? If some other relaxation factor(s) than 2 should be considered, please indicate so in the Comments field.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Option(s)** | **Comments** |
| FUTUREWEI1 | PT1, PT2 | Given the interest during R18 discussions, we should continue examining process relaxation.  Both options have been examined in R17. However, more companies should provide results for CSI relaxation in order to evaluate the technique as the number of results was limited. |
| Spreadtrum | Option PT1 | Open to Option PT2 |
| CMCC | PT1,PT2 |  |
| CATT |  | We still feel no need to reopen Rel-17 discussion. Another thing is that in the SID relaxing processing timeline is not standalone approach. |
| vivo | Option PT1, Option PT2 | In order to reduce the UE cost, both data and CSI processing time should be relaxed |
| Sharp | PT1,PT2 |  |
| Transsion | PT1,PT2 |  |
| Nordic | **PT1,PT2** | We support both |
| NEC | PT1 |  |
| ZTE, Sanechips | PT1, PT2 | Some new evaluation for R18 RedCap is needed, e.g., additional complexity reduction based on R17 RedCap need to be evaluated. |
| Ericsson | PT1, PT2 | As relaxed processing timeline is not listed as a standalone technique in the SID, it may not be necessary to provide complexity evaluation results for these options, i.e., it may be enough to report complexity evaluation results for combinations with these options in TR clause 7.5, but it is still good to have a TR clause 7.4 describing other aspects of relaxed processing timeline. |
| DOCOMO | PT1, PT2 |  |
| Samsung | PT1 | Open to PT2 |
| IDCC | PT1, PT2 |  |

7.5 Combinations of UE complexity reduction features

This section focuses on identifying potential combinations of further UE complexity reduction features which need to be evaluated. Contributions present various combinations of the potential complexity reduction features/options discussed in the previous sections. Combinations of relaxed processing time with bandwidth reduction and peak data rate reduction options are generally considered in the contributions [9, 10, 12, 14, 25, 27]. However, since the bandwidth reduction techniques naturally result in the peak data rate reduction, combinations of BW reduction and peak data rate reduction techniques are not considered in most of the contributions. Specifically, contribution [12] points out that it is not necessary to combine the UE bandwidth reduction and reduced UE peak data rate in FR1, since a similar effect can be achieved by both solutions.

Meanwhile, one contribution [21] presents the combination of TBS restriction with bandwidth reduction for further peak rate reduction. Also, [39] indicates that whether both UE bandwidth reduction and reduced UE peak data rate can be selected or only one is down selected depends on not only the cost reduction, but also the performance impacts and specification effort.

In this regard, it can be discussed whether combinations of UE bandwidth reduction and UE peak data rate reduction are feasible options. Therefore, the following question can be considered:

**FL1 High Priority Question 7.5-1a: Should any combination(s) of the further UE bandwidth reduction options listed in Section 7.2 and the UE peak data rate reduction options listed in Section 7.3 be studied? Please elaborate in the Comments field.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI1 |  | From initial analysis, the complexity reduction for most individual techniques is generally small. In order to have a meaningful reduction for Rel-18, combinations of techniques will be needed. How to limit the number of combinations to examine is the challenge. |
| Sierra Wireless |  | Number of combinations should be limited. |
| Spreadtrum |  | We prefer to identify the most popular solutions first, i.e., after resolve the question of 7.2-1a and 7.3-1a, and then consider whether and how to combine. |
| CMCC |  | According to our understanding, when the bandwidth is reduced to 5MHz, peak data rate is also reduced, further reduce peak data rate may not bring significant cost reduction. And there will be only one type of R18 RedCap UE, except for the cost reduction, the design is better to satisfy the date rate requirement for different bandwidth, 1Rx/2Rx, modulation order combinations, combination of UE bandwidth of UE peak data rate reduction should be carefully examined. |
| CATT |  | Assuming that the following cases are already evaluated in standalone study, i.e. in either BW reduction or PR reduction:   * (RF: 5MHz, BB: 5MHz) + No further PR limit * (RF: 20MHz, BB: 5MHz) + No further PR limit * No BW reduction (all 20MHz) + (PR: 10Mbps)   Depending on the interest of the majority group, the following combination can be considered:   * (RF: 5MHz, BB: 5MHz) + (PR: 10Mbps) * (RF: 20MHz, BB: 5MHz) + ( PR: 10Mbps) |
| vivo | Y | Similar as in Rel-17, we think all the BW reduction options can be combined with Option PR5 of relaxation of the maximum modulation order from 64QAM to 16QAM. |
| Qualcomm | N | For BW reduction options (regardless of RF BW reduction or BB BW only reduction), the peak rate is naturally reduced and achieving the required bitrate (close to 10Mbps) without considering any peak data rate reduction schemes. Therefore, no further peak data rate reduction options are required for BW reduction options. If we consider combination of those two, it will bring too many combination options in the combination sets. |
| Transsion |  | The combination of the further UE bandwidth reduction options and the UE peak data rate reduction options may result in more cost reduction than single reduction option. |
| Nordic |  | We would like to avoid putting restrictions on combinations and this point |
| ZTE, Sanechips |  | Not all the combination should be studied. We need to determine the detailed combinations for evaluation, which depends on the discussion in 7.2 and 7.3.  Additionally, when calculating the complexity reduction based on combination, the calculating method should be discussed and aligned. |
| Ericsson | N | For bandwidth reduction options where the bandwidth reduction results in a peak rate reduction close to 10 Mbps, there is no need to evaluate the combination of that bandwidth reduction option with some explicit peak rate reduction option(s). |
| DOCOMO |  | We share the similar view with companies that the combination of complexity reduction techniques needs to be considered to achieve further complexity reduction compared to Rel-17 RedCap. The detailed combinations can be discussed after some progress for the discussion of section 7.2/7.3. |
| Samsung |  | We treat them as either A or B, but not combined. The only combination allows is timeline relaxation. |
| IDCC | N | We do not see a need for this. |

While the exact sets of combination of techniques depend on the outcome of previous sections regarding the adopted options for evaluations, the two main sets of combinations are as follows:

* **Combination set 1:** Different combinations of UE bandwidth reduction options and relaxed processing time options.
* **Combination set 2:** Different combinations of UE peak data rate reduction options and relaxed processing time options.

**FL1 High Priority Question 7.5-2a: Can the following combination sets of complexity reduction features be considered as a starting point for the Rel-18 evaluations?**

* **Combination set 1: Different combinations of UE bandwidth reduction options and relaxed processing time options.**
* **Combination set 2: Different combinations of UE peak data rate reduction options and relaxed processing time options.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI |  | While it may be easier to discuss sets, the problem is the combination sets are not necessarily exclusive. A peak data rate reduction is possible with a 5 MHz BW. We can also have a combination of BW reduction and peak data rate (like modulation) and processing. Thus, it is somewhat difficult to create meaningful sets. |
| Spreadtrum | Y but | We think the study priority of these two combinations is high but other combinations are not preclude.  We indicated that it is not necessary to combine the UE bandwidth reduction and reduced UE peak data rate in our contribution, but for now, we are open to this combination, as some companies point out even the BW is reduced to 5MHz, the supported peak data rate is still higher than 10Mbps (the target data rate of R18). |
| CMCC | Y |  |
| vivo | Y |  |
| Qualcomm | Y | At least for looking at the maximum possible cost saving, we prefer to study the different combinations of complexity reduction features. |
| Transsion | Y |  |
| Nordic | N | This proposal is pre-mature at this point. |
| ZTE, Sanechips | Y |  |
| Ericsson | Y |  |
| DOCOMO |  | We are fine with both Combination set 1 and 2 as a starting point in general. In addition to them, following two combinations can be considered depending on the discussion outcome of previous section.   * **Combination set 3: Different combinations of UE bandwidth reduction options and UE peak data rate reduction options.** * **Combination set 4: Different combinations of UE bandwidth reduction options, UE peak data rate reduction options and relaxed processing time options.** |
| Samsung | Y | But need to further clarify the scope of this SI. |
| IDCC | Y |  |

In addition to the main complexity reduction features identified in the SID [1], a few contributions [9, 18, 20, 25, 31, 32, 35] point out other potential complexity reduction features for Rel-18. Specifically, the following aspects are discussed in these contributions:

* Reduced number of HARQ buffer processes [9, 18, 20, 25, 32]
* HD FDD complexity reduction [31, 32, 35]
* PDCCH monitoring reduction [35]

**FL1 High Priority Question 7.5-3a: In addition to the complexity reduction features/options described in previous sections, should RAN1 prioritize a study of any other aspects related to Rel-18 further UE complexity reduction?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI1 | Y | Studying reduction of the complexity for control processing, including PDCCH monitoring reduction. |
| Spreadtrum |  | Open to other features/options, if the TU permits |
| CMCC |  | These are low priority. |
| CATT |  | Considering that the group is now facing a lot of options in BW reduction and PR reduction, we prefer prioritizing those who are already in the SID scope. |
| vivo |  | Reduced number of HARQ buffer processes can be studied as it is related to UE data rate reduction.  Others are not in SID scope. |
| Qualcomm | Y | We prefer to see the cost reduction for PDCCH monitoring reduction. There are some reasons for that:  1. The reduced PDCCH monitoring was studied in Rel-17 but it was not from the cost saving context but from the power saving context. That was because the DL control processing & decoder block shows very small portion of the total cost in Rel-15 reference and corresponding cost reduction would be also very small if any relaxation is applied. However, the portion of DL control processing & decoder block has been increased to about 20% of the total baseband cost of Rel-17 baseline UE (based on cost breakdown of Rel-17 RedCap UE in TR 38.875), so the corresponding cost saving would be much more significant if reduced PDCCH monitoring is applied to Rel-17 baseline.  2. We already have sufficient study on reduced PDCCH monitoring in Rel-17 RedCap TR, which can be simply reused for Rel-18 (no duplication of the study is needed). Only required thing is the cost breakdown, which was not done during Rel-17. |
| Transsion |  | If the TU permits, we are open to talk about these feature. |
| Nordic | Y | Modifications to R17 HD-FDD duplexing can clearly reduce processing peaks/ peak rates and thus should be studied as priority according to WID. This because UE does not need to process UL and DL data channels at the same. Ultimately reduce cost of   * DL control processing & decoder * UL processing block |
| NEC |  | As TU is limited, they should be of lower priority. |
| ZTE, Sanechips |  | They can be deprioritized to be considered at this point. |
| Ericsson |  | Considering the limited time available to conclude the Rel-18 eRedCap SI, the study should focus on UE bandwidth reduction, UE peak rate reduction, and UE processing timeline relaxation. |
| DOCOMO |  | At least the reduced number of HARQ processes should be considered, which was studied but not adopted for Rel-17. We are also open to study for other complexity reduction techniques, i.e., HD FDD complexity reduction and PDCCH monitoring reduction. |
| Samsung |  | We suggest to focus on the SIs. |
| IDCC |  | We do no think so due to limited TU. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
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| [2] | [R1-2204058](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204058.zip) | Work plan for Study on further NR RedCap UE complexity reduction | Rapporteur (Ericsson) |
| [3] | [R1-2203121](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203121.zip) | Draft skeleton for TR 38.865 Study on further NR RedCap UE complexity reduction | Rapporteur (Ericsson) |
| [4] | [TR 38.875 V17.0.0](https://www.3gpp.org/ftp/Specs/archive/38_series/38.875/38875-h00.zip) | Study on support of reduced capability NR devices (Release 17) | 3GPP |
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| [14] | [R1-2203572](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203572.zip) | Techniques to further reduce the complexity of RedCap devices | vivo, Guangdong Genius |
| [15] | [R1-2203600](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203600.zip) | Discussion on further RedCap UE complexity reduction | ZTE, Sanechips |
| [16] | [R1-2203661](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203661.zip) | Discussion on potential solutions to further reduce UE complexity | China Telecom |
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| [18] | [R1-2203827](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203827.zip) | Discussion on the potential complexity reduction solutions for further UE complexity reduction | Xiaomi |
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| [21] | [R1-2204038](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204038.zip) | Further UE Complexity Reduction | Nokia, Nokia Shanghai Bell |
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| [23] | [R1-2204255](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204255.zip) | On further RedCap UE complexity reduction features | Apple |
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| [25] | [R1-2204389](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204389.zip) | Discussion on potential solutions for further UE complexity reduction | NTT DOCOMO, INC. |
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| [31] | [R1-2204747](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204747.zip) | On further complexity reduction of NR UE | Nordic Semiconductor ASA |
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