3GPP TSG-RAN WG1 Meeting #109-e R1-22xxxxx

e-Meeting, 9th – 20th May 2022

**Agenda Item: 9.6.1**

**Title: FL summary #2 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 FL3. The discussion in the previous round is captured in the FLS in [50].

Follow the naming convention in this example:

* *eRedCapComplexityFLS2-v000.docx*
* *eRedCapComplexityFLS2-v001-CompanyA.docx*
* *eRedCapComplexityFLS2-v002-CompanyA-CompanyB.docx*
* *eRedCapComplexityFLS2-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 *eRedCapComplexityFLS2-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *eRedCapComplexityFLS2-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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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.

**FL3 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** |
| FUTUREWEI | 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 |  |
| LGE | Y |  |
| SONY | Y |  |
| Intel | Y |  |
| OPPO | Y |  |
| Xiaomi | Y |  |
| Nokia, NSB | Y |  |
| Huawei, HiSilicon | Y |  |
| FL2 | Based on the received responses, the following proposal can be considered.**High Priority Proposal 6.1-1b: For cost reduction estimation, the detailed cost breakdown for the Rel-15 reference NR devices (as provided in Table 6.1-1 in TR 38.875 [4]) is reused.** |
| FL3 | The following agreement was made in the online (GTW) session on Thursday 12th May:Agreement:For cost reduction estimation, the detailed cost breakdown for the Rel-15 reference NR devices (as provided in Table 6.1-1 in TR 38.875) is reused. |

**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.**

|  |  |  |
| --- | --- | --- |
| **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. |
| LGE | Y | Taking the least complex (or most cost efficient) Rel-17 RedCap device for comparison with the Rel-18 RedCap study seems reasonable to us. Taking the HD-FDD as baseline in FDD bands is fine for us. Also looking into both the HD-FDD and FDD in FDD bands is fine for us. |
| SONY | Y | Include HD-FDD in the Rel-17 baseline. Including HD-FDD in the Rel-17 baseline does not preclude complexity reduction of FD-FDD UEs. |
| Intel | Y |  |
| OPPO |  | We think HD-FDD should be removed as this is not baseline case. Too much impact by HD-FDD in performance. BTW, FR1 also have TDD. |
| Xiaomi |  | Both FD-FDD and TDD shall be the baseline |
| Nokia, NSB | Y |  |
| Huawei, HiSilicon |  | OK with (20 MHz, DL 64QAM) while excluding HD-FDD.We could assume all networks support 20Mhz, 1Rx, 1 layer and DL 64QAM because the network can configure and schedule a legacy UE with such setting. However, we cannot assume HD-FDD is supported by all networks since it is not a mandatory UE feature for Rel-17 RedCap and it also requires non-trivial gNB implementation. With limited access to network, it is not true that UEs can always get cost reduction from HD-FDD. Therefore, HD-FDD cannot be a baseline. FD-FDD and TDD should be the baseline.Regarding 1Rx or 2 Rx, we prefer to also evaluate Rel-17 2Rx v.s. Rel-18 2Rx because 2Rx has better performance than 1Rx for all use cases while 1Rx is mainly used for wearable use case only. We believe Rel-18 RedCap is not limited to wearable UE only. Therefore, suggest both 1Rx and 2Rx as baseline. |
| FL2 | A slight majority of the received responses answered yes, whereas almost half of the responses express that the complexity reduction evaluation should include comparison with a reference Rel-17 RedCap UE that supports FD-FDD. Some responses indicated that they would be ok with two sets of evaluation results, one set comparing Rel-17 FD-FDD UEs with Rel-18 FD-FDD UEs and another set comparing Rel-17 HD-FDD UEs with Rel-18 HD-FDD UEs. One response proposed to evaluate both UEs with 1 Rx and UEs with 2 Rx.**High Priority Proposal 6.1-2b: For comparison with a Rel-17 baseline when evaluating the potential Rel-18 UE complexity reduction features,*** **The Rel-17 RedCap UE supports 20 MHz, 1 Rx, 1 layer, DL 64QAM, FD-FDD or TDD.**
* **In addition, optional results for the following comparisons can also be reported:**
	+ **Results for HD-FDD UEs**
	+ **Results for UEs with 2 Rx**
* **In all comparisons, the UEs being compared have the same number of antenna branches, the same number of layers, the same maximum supported modulation order, and the same duplex mode (among HD-FDD, FD-FDD, and TDD).**
 |
| FL3 | The following agreement was made in the online (GTW) session on Thursday 12th May:Agreement:For comparison with a Rel-17 baseline when evaluating the potential Rel-18 UE complexity reduction features,* The Rel-17 RedCap UE supports 20 MHz, 1 Rx, 1 layer, DL 64QAM, UL 64QAM, FDD or TDD.
* In addition, optional results for the following comparisons can also be reported:
	+ Results for HD-FDD UEs
	+ Results for UEs with 2 Rx
* In all comparisons, the UEs being compared have the same number of antenna branches, the same number of layers, the same maximum supported modulation order, and the same duplex mode (among HD-FDD, 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** |
| FUTUREWEI | 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. |
| LGE | N | Unless the impact is significant, and we think it is not, we prefer to rely on the existing setup in TR 38.875. |
| SONY |  | Our preference is to focus on RAN1 aspects, hence we would not consider L2 buffer size. We agree with Spreadtrum’s comment that “**at least capture the information (e.g., the memory cost can be reduced by R18 features) in the TR**” |
| Intel | N | We prefer to not consider it. Otherwise, as commented by Futurewei, we need to adjust the reference model, and the cost breakdown for Rel-17 UE too.  |
| OPPO |  | We can consider it as additional justification and does not affect the template.  |
| Xiaomi |  | We are open to discuss. |
| Nokia, NSB | N | This should not be evaluated since there is no agreed evaluation methodology at the physical layer and we lack a baseline for Rel-17 RedCap UE. |
| Huawei, HiSilicon |  | Open to consider |
| FL2 | Based on the received responses, the following proposal can be considered.**High Priority Proposal 6.1-3b: The impact on memory size/cost/complexity (external to the RF and BB parts) can be studied and captured in the TR, but it is not included in the quantitative UE complexity reduction estimates.** |
| FL3 | The proposal above was discussed in the online (GTW) session on Thursday 12th May. The latest version of the proposal discussed during the session looked like this:

|  |
| --- |
| The impact on cost/complexity (external to the RF and BB parts) can be studied and captured in the TR, but it is not included in the quantitative UE complexity reduction estimates.FFS： memory size, whether/how to be captured in the TR |

Based on the discussion, the following updated proposal can be considered.**High Priority Proposal 6.1-3c:*** **Study of the impact on memory size/cost/complexity (external to the RF and BB parts) from the studied UE complexity reduction features is optional.**
	+ **This potential impact will not be included in the quantitative UE complexity reduction estimates.**
	+ **L2 buffer size assumptions can be based on TS 38.306 clause 4.1.4 (“Total layer 2 buffer size for DL/UL”).**
 |
| Nordic | Y |  |
| vivo | Y |  |
| FUTUREWEI | N | The techniques in the scope of the SID are to reuse the methodology from the Rel-17 study (which we confirmed yesterday). This technique will show no benefit under the agreed methodology. The current wording seems to allow an SI exception for this technique, which in our view is not warranted. As commented, there should be “FFS whether/how to capture in the TR” |
| CATT | Y | Also OK to add ‘FFS whether/how to capture in the TR’ as a sub-bullet. |
| Panasonic | Y |  |
| Spreadtrum | Y | @ FUTUREWEI, from our perspective, memory size/cost/complexity reduction is not a technique, it is simply a positive consequence of the introduction of R18 technique (e.g., Memory cost will be reduced by BW reduction and/or reduced peak data rate). What we need to do is show this positive information to the vertical. As mentioned by Johan, **we don’t even need the quantitative estimates, maybe just a qualitative description is enough.** |

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** |
| FUTUREWEI | 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 |  |
| LGE | Y in general | Okay in general. But, how it is captured in the TR can be discussed separately.  |
| SONY | Y | The TR should say something about performance impacts, coexistence impacts and specification impacts. We would like to avoid a deep-dive / large simulation campaign, given the limited number of TU in this study. Some results from TR38.875 can be included in the current TR or cross-referenced from the current TR. |
| Intel | Y |  |
| OPPO | Y |  |
| Xiaomi | Y |  |
| Nokia, NSB | Y |  |
| Huawei, HiSilicon | Y | But better not to overlap with the discussion for TR skeleton. |
| FL2FL3 | Based on the received responses, the following proposal can be considered. The detailed meaning of “Performance impacts” remains to be decided.**High Priority Proposal 6.1-4b: For each potential Rel-18 further UE complexity reduction feature, at least the following aspects will be studied:*** **UE complexity reduction**
* **Performance impacts**
* **Network and coexistence impacts**
* **Specification impacts**
 |
| Nordic  | Y |  |
| vivo | Need clarification | We are generally fine with the proposal. But we see some overlapping between Performance impacts and NW impacts. So, we would like to clarify what metrics are included in performance impacts e.g. coverage, latency etc. and what are covered by NW impacts e.g. Network capacity and spectral efficiency? |
| FUTUREWEI | Y | For Vivo's question, most of the network aspects raised in the Rel-18 workshop discussions were deployment related not capacity related. We do not think network capacity needs to be evaluated for Rel-18, but if RAN1 agrees to do so, it would be under Performance. |
| Lenovo | Y |  |
| CATT | Y | In fact these are mostly required by SID. |
| Panasonic | Y |  |
| Sierra Wireless | Y | Yes, as these follow guidelines in SID. |
| Spreadtrum | Y |  |
| Qualcomm | 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?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Option(s)** | **Comments** |
| FUTUREWEI | 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: BW32nd:BW2, BW1, BW53rd: 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., 3,4,5,6For 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 |  |
| LGE | BW1, BW3 | BW1 and BW3 should be essential for this study. The benefits of BW2 compared to BW1/BW3 would not be significant, but can be studied if there is enough support. |
| SONY | BW1, BW3, BW5 | We have tried to choose a subset of reasonably different options. While some of the other options have merit, studying them might not lead to a great deal of additional insight. |
| Intel | BW1, BW2, BW3 | One clarification question on BW3, is the 5MHz BB for data channel limited to localized 25 PRB? From our view, there will no difference between localized 25 PRBs or distributed 25 PRBs. If there is a preference to categorize distributed 25 PRBs for data channel as PR3 for peak rate reduction, it needs to clarify that the number of PRBs in PR3 is the hard limit for data transmission, but not a value only for peak rate calculation.  |
| OPPO | BW1 | That only option will make the evaluation simplified.Other options may means the same as peak data rate reduction. |
| Xiaomi | BW1, BW3 | 1. On one hand, to obtain more cost saving gain, both RF and BB BW reduction to 5MHZ for all channels is the best way.
2. On the other hand, in order to avoid affecting the transmission of control and reference signals, only data channel BW reduction is the best choice.

Option BW2 with less cost gain compared with BW1 and can’t avoid affecting the transmission of control and reference signals, which can’t accept by us. |
| Nokia, NSB | BW1, BW3 | We think BW1 and BW3 are the two main options to be evaluated as BW1 provides the largest complexity reduction while BW3 has the smallest system/specification impact. Other options are hybrids of these two options and we don’t think they offer good trade-offs between complexity reduction and system/specification impact. We also need to minimize the number of options to evaluate due to the tight schedule and limited TU. Some specific comments –BW2 – only PBCH would have no impact compared to BW1 and this is too minor to consider as a separate option.BW4 – we prefer not to reduce data channel bandwidth beyond 5 MHz but instead use TBS restriction for further complexity reduction to reach 10 Mbps peak data rate.BW5 – this option still requires all channels to support 20 MHz (e.g to receive SIB, to transmit Msg3), therefore we do not see how this will bring about meaningful complexity reduction.BW6 – this is similar to BW3 but we are not sure it would be beneficial since 5MHz UL is sufficient to meet the peak data rate requirement.BW7 – not sure if it is feasible to have different RF+BB for UL and DL.BW8 – this would not save as much as BW1 but would still have all the same issues except for PBCH reception at 30 kHz SCS. |
| Huawei, HiSilicon | BW1, BW3 |  |
| FL2FL3 | Study of options BW1 and BW3 are supported by a large majority of the received responses. About a quarter of the responses want to study option BW2. The other options receive very limited interest. Based on the responses the following proposal can be considered.**High Priority Proposal 7.2-1b:*** **The following options for further UE bandwidth reduction will be studied:**
	+ **Option BW1: Both RF and BB bandwidths are 5 MHz for UL and DL.**
	+ **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.**
* **In addition, optional results for the following option can also be reported:**
	+ **Option BW2: 5 MHz BB bandwidth for data and control channels with 20 MHz RF bandwidth for UL and DL.**
 |
| Nordic  | N | We do no see BW3 to be different to PR3, option should be studied only once, not twice. **In addition, we hope that 3GPP remains technical group, not a political group where we vote to select technical solutions.** Here are the arguments why IDLE/CONNECTED dependent BW reduction and UL/DL dependent reduction should be studied.**IDLE/Connected** * reception of common IDLE DL signals is not so challenging compared to RRC connected, **IDLE is using clearly less BB processing power than RRC connected.**
	+ Even though FFT must support 20MHz for CORESET#0/commonCORESET + broadcast, the buffering need is reduced, this because UE need to monitor significantly less PDCCH candidates in IDLE compared to RRC connected
	+ The timelines and/or max TBS sizes for processing SIBs, Paging, MSG2 are much lower than for unicast or could be further reduced.
	+ **As a consequence, chipset may be designed with less processing power**

**Asymmetric UL/DL (for HD-FDD)*** If device has duplexer, it will take care of inter-modulation products and harmonics leaking from UL to the closest DL bands. In HD-FDD, there is no duplexer, so with keeping RF open to 20MHz UE/device must invest into more linear amplifier and/or invest into additional filters, which in fact are FDD band specific. With reducing UL RF to 5MHz, no filters after power amplifier are needed and power amplifier itself may be cheaper.
* **In R17 Redcap, cost for duplexer was removed, but additional costs to support FDD bands with HD and 20MHz UL were omitted in R17 study.**
 |
| Vivo |  | We would like to understand what “optional results can also be reported” actually means. According to our understanding, companies are always free to choose all or a subset of BW1/2/3 for study and report the cost estimation analysis. Or is it the intention to say we will draw conclusion for BW1/3 but may not for BW2? |
| FUTUREWEI | Y with comment | We think BW5 is attractive in reusing the BWP framework but can accept not studying it. If more options beyond BW1/2/3 are included, we would like to see BW5 back. Given the similarity to BW2, we can add some qualitative text for BW5 in the sections for BW2 |
| Lenovo | Y | Reduction of UE BW naturally reduces UE peak data rate. This is reason there are some overlapping of candidates in 7.2 and 7.3, say BW3 and PR3. Per email discussion, the difference is regarding the localized/distributed resource allocation. So maybe good to clarify PR3 is for distributed resource allocation only.  |
| CATT | Y |  |
| Panasonic | Y |  |
| Sierra Wireless | Y | We think that BW3 should be studied as it has the smallest specification impact. |
| Spreadtrum | Y |  |
| Qualcomm | Y with comment | Need to clarify BW3 whether 5MHz restriction is applied only to UE-specific data channels or applied to all data channels including common data channels like SIB1 PDSCH. |

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 $(v\_{Layers}^{\left(j\right)}⋅Q\_{m}^{\left(j\right)}⋅f^{\left(j\right)}\geq 4)$ 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 reduction [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)
 |
| 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 PR2Option 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 REIn 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 alreadyAgain 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 $(v\_{Layers}^{\left(j\right)}⋅Q\_{m}^{\left(j\right)}⋅f^{\left(j\right)}\geq 4)$ (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 |  |
| LGE | PR1, PR2, PR3 | Open to study PR1/2/3, but we expect the expected cost/complexity reduction gain is not comparable to the further UE bandwidth reduction. |
| SONY | PR2 | This seems like the most straightforward way of reducing the peak data rate. It is the approach that was adopted at the outcome of TR36.888. |
| Intel | PR1, PR2, PR3 (limit the max number of PRBs or REs) | For PR1/4, it is clear to put limitation on the formula for peak data rate in 38.306. Then, we have the following clarification questions. For PR3, is it the intention to put a hard limitation on PRBs for actual scheduled PDSCH/PUSCH, or just to use a limited max number of PRB in the formula for peak data rate in 38.306 (i.e., the scheduled PRB can be larger as long as data rate does not exceed the peak data rate)? Similar clarification is needed for PR5 (i.e., 16QAM is used in the formula but gNB can schedule a higher modulation order as long as data rate does not exceed the peak data rate). As a variance to PR3, it can be considered to limit the maximum number of REs for PDSCH/PUSCH transmission. Note: if the maximum number of REs can be limited, it can also get the benefit of reduced post-FFT buffer which is similar to limit the number of PRBs.  |
| OPPO | PR1, PR2, PR3 |  |
| Xiaomi | PR1, PR2, [PR3,] PR4 | PR3 is just the same as the Option BW3 for further BW reduction discussed in Section 7.2, and duplicate work should be avoid. |
| Nokia, NSB | PR2 | PR3 – we feel it is better to restrict TBS rather than number of PRBs as restricting the number of PRBs can reduce DL throughput for cell-edge UEs.PR5 – we do not prefer to limit peak rate via 16-QAM as we expect this to reduce spectral efficiency significantly. |
| Huawei, HiSilicon | PR2, PR3 |  |
| FL2FL3 | Study of options PR1, PR2 and PR3 are supported by most of the received responses. The other options receive very limited interest. Based on the responses the following proposal can be considered.**High Priority Proposal 7.3-1b:*** **The following options for further UE peak rate reduction will be studied:**
	+ **Option PR1: Relaxation of the constraint** $(v\_{Layers}^{\left(j\right)}⋅Q\_{m}^{\left(j\right)}⋅f^{\left(j\right)}\geq 4)$ **for peak data rate reduction.**
	+ **Option PR2: Restriction of maximum TBS for PDSCH and PUSCH.**
	+ **Option PR3: Restriction of maximum number of PRBs (or bandwidth) for PDSCH and PUSCH.**
 |
| Nordic  | N | PR3 overlaps with BW3, solution should be studied only once.  |
| vivo |  | We also wonder how much difference is between PR3 and BW3. We can understand that the PDSCH allocation should be within 5MHz for BW3 while the PDSCH allocation can be distributed in frequency with total size not exceeding 25RB (assuming 15KHz SCS). But from UE buffering perspective, the two options seem the same, i.e UE can reduce the buffering by only buffering the interested RBs after PDCCH is decoded.  |
| FUTUREWEI |  | PR1 seems like another way to consider L2 buffer size. The complexity of L2 buffer size cannot be determined with the evaluation methodology.PR2 seems like an academic exercise. Calculations can be made back and forth between the TBS and RBs used is what other techniques do, which would be similar enough. It is similar to 36.888, but we feel it is a low priority.PR3 is indeed similar to BW3. We are open to discuss more whether to focus on one and just mention the other qualitatively in those sections.For all of these, it is important that we have a similar comparison to BW1, i.e., at least results for TBS or RBs should be included in the TR that match that the TBS and RBs used for BW1. |
| Lenovo | Y | To differentiate PR3 with BW3, the “(or bandwidth)” shall be removed and clarify PR3 should be for distributed resource allocation only.  |
| CATT | Y | Also open to remove PR3 if we agree BW3.  |
| Panasonic | Y |  |
| Sierra Wireless | Y | Agree with Lenovo, we should remove “(or bandwidth)” in PR3. |
| Spreadtrum | Y | **Option PR1,** @ FUTUREWEI, for your comments about 7.3-1b, “PR1 seems like another way to consider L2 buffer size. The complexity of L2 buffer size cannot be determined with the evaluation methodology”. Do you mean we don’t need to consider any techniques that affect L2 buffer size? There is a very interest thing that almost all the R18 techniques(BW reduction, reduced peak data rate) will reduce the L2 buffer size. If that's the logic, there's nothing we can do for R18 RedCap.**Option PR3:** Maybe clarifications for PR3 and BW3 are needed, if PR3 is the same as BW3, solution should be studied only once. |
| Qualcomm |  | As Lenovo mentioned, need to remove “(or bandwidth)” to differentiate PR3 from BW3. We think that PR1 and PR2 is almost the same especially for cost breakdown. And actually PR1 can effectively include the PR2 because the peak rate reduction by relaxing the constraint $(v\_{Layers}^{\left(j\right)}⋅Q\_{m}^{\left(j\right)}⋅f^{\left(j\right)}\geq 4)$ will consequently limit the max TBS by itself. It is redundant to study both. We suggest to remove PR2 or at least put it as an optional study. |

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** |
| FUTUREWEI | 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 |  |
| LGE |  | We share the view with CATT in that we should avoid reiterating the same evaluations and discussions on this topic and should only consider studying them if there is any further cost/complexity benefits identified in conjunction with the UE bandwidth reduction and/or peak rate reduction. |
| SONY  | PT1, PT2 |  |
| Intel | PT1, PT2 |  |
| OPPO | PT1, PT2 |  |
| Xiaomi | PT1, PT2 |  |
| Nokia, NSB | PT1 | We are OK to consider relaxation factor of 2 for N1/N2.Relaxation of UE processing time for CSI in terms of Z and Z’ was already considered in Rel-17 and not adopted for evaluations. We don’t see compelling reasons to consider this again in Rel-18. |
| Huawei, HiSilicon | PT1, PT2 |  |
| FL2FL3 | A large majority of the received responses express an interest in studying options PT1 and PT2. Based on the responses the following proposal can be considered.**High Priority Proposal 7.4-1b:*** **The following options for relaxed UE processing timeline will be studied:**
	+ **Option PT1: Relaxation of UE processing time for PDSCH/PUSCH in terms of N1 and N2**
	+ **Option PT2: Relaxation of UE processing time for CSI in terms of Z and Z**
* **UE complexity reduction estimates for relaxed UE processing timeline are only reported for combinations with UE bandwidth reduction or UE peak rate reduction.**
 |
| Nordic | Y |  |
| vivo | Y |  |
| FUTUREWEI | Y | While we understand the use of the combination, we still would like to see the individual results for PT1 and PT2 reported for comparisons. |
| CATT |  | With the understanding that this will only be reported for combination case, we wouldn’t object if the majority would like to do so. |
| Panasonic | Y |  |
| Spreadtrum | Y |  |

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** |
| FUTUREWEI |  | 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.  |
| LGE |  | Combinations of 7.2 and 7.3 need to be studied as some of the standalone benefits may disappear when they are jointly evaluated. This will help removing duplicate efforts to reduce the cost/complexity. |
| SONY | Y | Bandwidth reduction and peak data rate reduction are different issues. It might be desirable to support a low peak data rate in a wide bandwidth in order to operate at a more robust frequency diverse low coding rate. |
| Intel | Y | We are supportive to allow the combination of BW reduction and peak data rate reduction. For 5MHz BW and 64QAM, the data rate is around 20Mbps, therefore, it is possible to further limit the peak data rate or the maximum TBS, for further complexity reduction.  |
| OPPO |  | We wonder if we made decision base on that in Rel17? |
| Nokia, NSB | Y | We support the combination as BW reduction to 5MHz still has peak data rates higher than 10 Mbps. We don’t prefer further BW reduction to reach 10 Mbps as restricting the number of PRBs can reduce DL throughput for cell-edge UEs |
| Huawei, HiSilicon |  | Prefer to achieve a limited number of combinations and avoid unnecessary overlaps between BW reduction to 5MHz and peak date rate reduction. |
| Panasonic | Y |  |

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.**

|  |  |  |
| --- | --- | --- |
| **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 |  |
| LGE |  | We prefer to comeback to this question once the discussion under 7.4 on the relaxed UE processing time settles down). |
| SONY | Y | Other combinations are not precluded. |
| Intel |  | We prefer to wait for a conclusion on 7.5-1a. In general, we prefer to evaluate all possible combinations to find the most favorite case for eRedCap.  |
| Nokia, NSB |  | We prefer to wait until the discussion on features is more stable. |
| Huawei, HiSilicon | Y | OK for a starting point. |
| FL2FL3 | Based on the received responses, the following proposal can be considered.**High Priority Question 7.5-2b: At least the following combination sets of complexity reduction features are used 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.**
 |
| Nordic  | N | We agree with Intel and Nokia that combinations depends on techniques which are not yet stable |
| vivo | Y |  |
| FUTUREWEI | N | It is difficult to discuss the combinations because the techniques are not settled. |
| Lenovo | N | Same view with Nordic and FUTUREWEI |
| CATT | Y in general | But the combination number may still be large, since we see 2 options for BW reduction (BW1, BW3), at least 2 options for peak data rate reduction (PR1, PR2, [PR3]), and 3 options for relaxed processing time (N, Z, N+Z). The combination number may be 2\*3 + 2\*3 = 12, which is huge.hope we can reduce the combination number, e.g. only consider relax N but not Z. |
| Panasonic |  | As commented by companies, the combination is difficult to judge for now. |
| Sierra Wireless | N | We prefer to wait until techniques are more settled. |
|  |  |  |

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 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** |
| FUTUREWEI | 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. |
| LGE | N | They should be deprioritized given the time for evaluation and discussion. But, among the techniques mentioned above, we are open to study HD-FDD type B for further cost/complexity reduction. |
| SONY | Y | We would be most interested in HD-FDD complexity reduction (for, e.g., the reasons stated by Nordic) and PDCCH monitoring reductions. |
| Intel | Y | Considering the benefit from BW reduction, peak rate reduction and relaxed processing time is not that large, it is preferrable to study more factors for a better design. Besides the three listed points, we think relaxed modulation order to 16QAM can be considered if the limitation on modulation order in PR5 is only for peak data rate calculation. |
| Xiaomi |  | They should be considered with lower priority due to the limited TU. |
| Nokia, NSB |  | These features should not be prioritized. We don’t think PDCCH monitoring reduction will bring any meaningful reduction in complexity and will increase blocking, especially if the control channel is limited to 5MHz. |
| FL2FL3 | Based on the received responses, the following proposal can be considered.**High Priority Question 7.5-3b: Study of the following complexity reduction techniques is not prioritized in this study item.*** **Reduced number of HARQ processes**
* **HD-FDD complexity reduction**
* **PDCCH monitoring reduction**
 |
| Nordic  | N | We still do not understand why enhanced HD-FDD should be excluded as it reduces peak rates for PDSCH and PUSCH, **well in scope of SID.**  |
| Vivo | Y | We think reduced number of HARQ processes can be studied as it is related to UE data rate reduction. But we can accept the proposal. |
| FUTUREWEI | Y |  |
| Lenovo | Y |  |
| CATT | Y |  |
| Panasonic | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| Qualcomm | N | The main concern for those items is the limited TU for the study item. However, as mentioned, we have done sufficient study for PDCCH monitoring reduction in Rel-17 including performance impact (blocking prob), coexistence, and specification impacts which are captured in TR 38.875 (section 8.2). The only thing we need to do is the cost breakdown study. We support to study PDCCH monitoring reduction, as it brings meaningful cost saving gain as well as additional UE power saving gain. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
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