3GPP TSG-RAN WG1 Meeting #103-e Tdoc R1-20xxxxx

e-Meeting, October 26th – November 13th, 2020

**Agenda Item: 8.6.1**

**Title: FL summary #8 for Potential UE complexity reduction features for RedCap**

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# 1 Introduction

This document captures the following RAN1#103e RedCap email discussion.

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| [103-e-NR-RedCap-02] Email discussion for potential UE complexity reduction features – Johan (Ericsson) |

The previous round of this email discussion is documented in FL summary #7 (FLS7) in [R1-2009795](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009795.zip).

This round focuses on the following items:

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| 1. TR clause 7.2.3: TP for reduced number of UE Rx branches on impact on power consumption
2. TR clause 7.2.4: TP for reduced number of UE Rx branches on impact on coexistence
3. TR clause 7.2.5: TP for reduced number of UE Rx branches on impact on specifications
4. TR clause 7.3.3: TP for UE bandwidth reduction on impact on data rates
5. TR clause 7.3.3: TP for UE bandwidth reduction on impact on power consumption
6. TR clause 7.3.4: TP for UE bandwidth reduction on impact on coexistence
7. TR clause 7.4.3: TP for half-duplex FDD operation on impact on data rates
8. TR clause 7.4.3: TP for half-duplex FDD operation on impact on latency and reliability
9. TR clause 7.4.4: TP for half-duplex FDD operation on impact on coexistence
10. TR clause 7.4.5: TP for half-duplex FDD operation on impact on specifications
11. TR clause 7.5.3: TP for relaxed UE processing time on impact on data rates
12. TR clause 7.5.3: TP for relaxed UE processing time on impact on power consumption
13. TR clause 7.5.4: TP for relaxed UE processing time on impact on coexistence
14. TR clause 7.5.5: TP for relaxed UE processing time on impact on specifications
15. TR clause 7.6.3: TP for relaxed maximum number of MIMO layers on impact on power consumption
16. TR clause 7.5.2: TP for relaxed UE processing time on UE complexity reduction for relaxed CSI computation time
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In ALL file names, please use hyphen characters (not underline characters) and include ‘v’ in front of the version numbers.

Follow the naming convention in this example:

* *RedCapComplexityFLS8-v000.docx*
* *RedCapComplexityFLS8-v001-CompanyA.docx*
* *RedCapComplexityFLS8-v002-CompanyA-CompanyB.docx*
* *RedCapComplexityFLS8-v003-CompanyB-CompanyC.docx*

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

* Assume CompanyC wants to update *RedCapComplexityFLS7-v008-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapComplexityFLS7-v008-CompanyB-CompanyC.checkout*
* CompanyC then has 30 minutes to upload *RedCapComplexityFLS7-v008-CompanyB-CompanyC.docx*
* If no update is uploaded in 30 minutes, other companies can ignore the checkout file.
* Note that the file timestamps on the server are in UTC time.

# 2 Updated text proposals

Based on email discussion responses in FLS7 ([R1-2009795](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009795.zip)), the following TP for TR 38.875 can be considered, where the change tracking is relative to the corresponding TPs in FLS7.

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| 7.2 Reduced number of UE Rx branches[…]7.2.3 Analysis of performance impacts[…]**Power consumption:**The instantenous power consumption in the RF and the baseband modules of the UE is expected to be reduced due to the use of fewer RF chains and the reduction in the complexity of multi-antenna processing. Depending on the traffic characteristics, the average power consumption of the UE can increase or decrease.[…]7.2.4 Analysis of coexistence with legacy UEsIn general, RedCap UEs with reduced number of Rx branches can coexist with legacy UEs. However, the presence of RedCap UEs with reduced number of Rx branches may impact the performance for legacy UEs if some broadcast channels are used for both legacy UEs and RedCap UEs. This is because, if there is no early indication of RedCap UE, both legacy UEs and RedCap UEs will be treated the same by the network, which will lead to conservative treatment of all UEs.Furthermore, due to the reduced downlink spectral efficiency, more resources may be needed for broadcast channels such as broadcast PDCCH. The need to use higher PDCCH aggregation levels for RedCap UEs may also increase the PDCCH blocking probability for legacy UEs if they share the same CORESET.7.2.5 Analysis of specification impactsFor reduced number of Rx branches, work in RAN4 may be required to define new receiver characteristics, demodulation performance requirements, and requirements relating to CSI reporting, RF, RRM, and other procedures, such as cell handover or (re)selection, radio link management and beam management. RAN4 may also need to evaluate and specify new minimum numbers of Rx branches for RedCap UEs in different bands. Impacts on RAN4 specifications may also extend beyond the mentioned aspects.Additionally, to address the performance and coexistence impacts identified in subcluses 7.2.3 and 7.2.4, specification work in other working groups may be needed.[…]7.3 UE bandwidth reduction[…]7.3.3 Analysis of performance impacts**Data rate:**Bandwidth reduction results in a reduction in the achievable peak data rate. However, all the bandwidth options (20 MHz in FR1, and 50 MHz or 100 MHz in FR2) considered in the RedCap study are enough for meeting the peak data rate requirements for the RedCap use cases, at least when the bandwidth reduction is not combined with other UE complexity reduction techniques, except in some TDD configurations. For peak rate impacts from combinations of UE complexity reduction techniques, see clause 7.8.3.[…]**Power consumption:**UE bandwidth reduction reduces the instantaneous power consumption of the RF and baseband modules during transmission and reception. However, depending on the traffic characteristics (e.g. due to prolonged continuous downlink and uplink transmission), the average power consumption of the UE can increase or decrease.[…]7.3.4 Analysis of coexistence with legacy UEsIn general, UE bandwidth options such as 20 MHz for FR1 UEs and 100 MHz for FR2 UEs achieve good coexistence performance with legacy UEs.* The 20-MHz bandwidth option for FR1 UEs allows a RedCap UE to reuse existing procedures for acquiring SSB, SIB1, other SIBs, RAR and Msg4.
* The 100-MHz bandwidth option for FR2 UEs achieves the same coexistence benefits, except that for certain configurations for SSB/CORESET multiplexing patterns 2 and 3, the UE needs to acquire SSB and SIB1 in a sequential manner. However, the sequential SSB/SIB1 acqisition for a RedCap UE does not cause any performance degradation to legacy UEs.
* The 50-MHz bandwidth option for FR2 UEs would result in coverage loss for PDCCH reception in CORESET#0 if CORESET#0 is configured to 69.12 MHz. In such cases, if coverage recovery is needed for PDCCH, PDCCH capacity of CORESET#0 may be affected, and this will have impact on legacy UEs. Furthermore, if early RedCap UE identification is not provided, supporting 50-MHz RedCap UEs requires the gNB to schedule the PDSCH of SIBs, RAR, and Msg4 within 50 MHz bandwidth. Such scheduling restrictions will have an impact on legacy UEs.

If RedCap and eMBB UEs share the same initial BWP in downlink and uplink for initial access procedure, and the number of RedCap UEs in the network is large, there may be impact to eMBB UE performance in initial BWP due to congestion and scheduling/configuration restriction (e.g. for RACH occasions).[…]7.4 Half-duplex FDD operation[…]7.4.3 Analysis of performance impacts[…]**Data rate:**There is minor impact from HD-FDD operation on instantaneous data rates for uplink or downlink, but HD-FDD reduces user throughput compared to FD-FDD, and it may not be feasible to meet the peak data rate requirements in downlink and uplink simultaneously.**Latency and reliability:**HD-FDD introduces longer latency than FD-HDD, especially in case of simultaneous downlink and uplink traffic, but the latency and reliability requirements of RedCap use cases can still be fulfilled at least for one direction (downlink or uplink).[…]7.4.4 Analysis of coexistence with legacy UEsIntroducing HD-FDD operation might make gNB scheduling more complicated. The impact due to the support for HD-FDD Type B operation is greater than for Type A.For initial access, supporting HD-FDD Type B operation might have a potential impact on the RACH procedure in that longer time gaps between messages might be needed. One example is the switching time from PRACH to Msg2. Supporting HD-FDD Type B operation may cause a longer switching time from PRACH to Msg2 to be used for all UEs, if the RedCap UEs are not identified in Msg1. This is not an issue for Type A due to its faster UL-to-DL switching capability.7.4.5 Analysis of specification impactsIntroducing support for HD-FDD operation may have the following impacts on RAN1 specifications.* Specifying DL-to-UL and UL-to-DL switching time
* Specifying how the UE handles DL/UL collision

Depending on the detailed solution, it may or may not be possible to reuse existing RAN1 specification for non-full-duplex operation for support of HD-FDD operation type A (but not for type B).Additionally, HD-FDD support also has the following impacts on RAN4 specifications.* Specifying applicable bands
* Specifying performance requirements such as reference sensitivity and RRM

7.5 Relaxed UE processing time[…]7.5.3 Analysis of performance impacts[…]**Data rate:**No impact on instantaneous peak data rate is expected, but the UE throughput may be reduced if the HARQ round trip time is extended. The throughput requirements identified for the RedCap use cases are still expected to be fulfilled.**Power consumption:**Relaxed UE processing time in terms of N1/N2 may allow for processing with lower clock frequency and lower voltage which may help reducing the UE power consumption. The impact on power consumption of relaxed UE processing time depends on implementation and traffic characteristics.[…]7.5.4 Analysis of coexistence with legacy UEsIn scenarios where RedCap UEs coexist with legacy UEs, relaxed UE processing time capability for RedCap UEs may increase the complexity for the scheduling.The relaxed UE processing time capability may cause potential coexistence issues with legacy UEs during initial access if early identification of RedCap UEs prior to Msg2 scheduling is not supported or conservative scheduling is not possible. If gNB schedules all UEs according to relaxed timing relationships for RedCap UEs, legacy UEs may experience an increase in control plane latency.7.5.5 Analysis of specification impactsA new UE processing time capability needs to be defined if relaxed UE processing time is introduced. New values of N1 and N2, as well as how the PDSCH processing time and PUSCH preparation time are determined by N1 and N2, need to be defined.Depending on the degree of relaxation of the N1 and N2 values, specification details on scheduling timing related to the default TDRA tables and HARQ-ACK timing range may also need to be updated.7.6 Relaxed maximum number of MIMO layers[…]7.6.3 Analysis of performance impacts[…]**Power consumption:**The reduced number of MIMO layers can result in lower instantaneous power consumption due to the reduced peak data rate and reduced complexity in processing a smaller maximum transport block size. Depending on the traffic characteristics, the average power consumption of the UE may increase or decrease. |

Since the email discussion is required to wrap up very soon, companies are encouraged to be flexible and accept the TP above as a whole. If there is an objection against some parts of the TP, companies are requested to propose a way forward that is more likely to be acceptable to the whole group in light of comments already received in FLS7 ([R1-2009795](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009795.zip)).

**Proposal 1: Adopt the TP in section 2 of this document as baseline text for TR 38.875.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| DOCOMO | Y |  |
| vivo | N | The following parts are NOT acceptable.7.2.3 Analysis of performance impacts**Power consumption:**The instantenous power consumption in the RF and the baseband modules of the UE is expected to be reduced due to the use of fewer RF chains and the reduction in the complexity of multi-antenna processing. Depending on the traffic characteristics, the average power consumption of the UE can increase or decrease.[Comment]: Evaluataion results in R1-2009212 has shown that reduced Rx has clear power saving benefit for various traffic models that agreed for RedCap. No other results have been provided to justfy the potential power consumption increase. [Possible wayforward]Alt 1: To keep the first sentence only which is always true from the power model. Alt 2: to delete the whole section about power consumption7.3.3 Analysis of performance impacts**Power consumption:**UE bandwidth reduction reduces the instantaneous power consumption of the RF and baseband modules during transmission and reception. However, depending on the traffic characteristics (e.g. due to prolonged continuous downlink and uplink transmission), the average power consumption of the UE can increase or decrease.[Comment]: There has been no evaluation results submitted. [Possible wayforward]Alt 1: To keep the first sentence only which is always true from the power model. Alt 2: to delete the whole section about power consumption7.6.3 Analysis of performance impacts[…]**Power consumption:**The reduced number of MIMO layers can result in lower instantaneous power consumption due to the reduced peak data rate and reduced complexity in processing a smaller maximum transport block size. Depending on the traffic characteristics, the average power consumption of the UE may increase or decrease.[Comment]: Evaluataion results in R1-2009212 has shown that reduced MIMO layer (as a natural consequence from reduced number of Rx) has clear power saving benefit for various traffic models that agreed for RedCap. No other results have been provided to justfy the potential power consumption increase. [Possible wayforward]Alt 1: To keep the first sentence only which is always true from the power model. Alt 2: To delete the whole section about power consumptionExcep the above three sections, we are fine with other parts of the TP.  |
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# 3 TP for UE complexity reduction for relaxed CSI computation time

RAN1#103e has agreed the following TP as baseline text for TR 38.875.

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| 7.5 Relaxed UE processing time7.5.1 Description of featureIn the RedCap study item, relaxed UE processing time is considered in terms of more relaxed N1/N2 values compared to those of UE processing time capability 1.In the study, for the purpose of evaluation, the relaxed UE processing time in terms of N1/N2 are assumed to be doubled compared to those of capability 1, i.e.,* N1 = 16, 20, 34, and 40 symbols for 15, 30, 60, and 120 kHz SCS (assuming only front-loaded DMRS)
* N2 = 20, 24, 46, and 72 symbols for 15, 30, 60, and 120 kHz SCS

In the study, for the purpose of evaluation, relaxed CSI computation time was also considered, assuming doubled Z/Z' compared to the values defined in TS 38.214 clause 5.4. |

TR clause 7.5.2 presents cost estimates for relaxed UE processing time in terms of N1/N2 but not for relaxed CSI computation time. Cost estimates for relaxed CSI computation time have been provided by Huawei/HiSilicon in [RedCapCost-HWHiSi for CSI computation time relaxation.xlsx](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Inbox/drafts/8.6/EvaluationResults/RedCapCost/Other/RedCapCost-HWHiSi%20for%20CSI%20computation%20time%20relaxation.xlsx). Based on this input, the following TP can be considered.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 7.5.2 Analysis of UE complexity reductionThe estimated cost for a device with relaxed UE processing time in terms of N1/N2 (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies, is summarized in Table 7.5.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction is ~6% for FR1 FDD, ~6% for FR1 TDD, and ~6% for FR2 TDD.Relaxed UE processing time in terms of N1/N2 potentially reduces UE complexity by allowing a longer time for the processing of PDCCH and PDSCH and preparing PUSCH and PUCCH. By comparing Table 7.5.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the cost of the following functional blocks can be reduced:* Baseband: Receiver processing block
* Baseband: LDPC decoding
* Baseband: DL control processing & decoder
* Baseband: UL processing block

Whether the relaxed UE processing time may reduce the cost/complexity in the ‘DL control processing & decoder’ block depends on the UE implementation.Furthermore, all sourcing companies indicated that these cost savings do not accumulate across supported bands.**Table 7.5.2-1: Estimated relative device cost for relaxed UE processing time in terms of N1/N2**

|  |  |  |  |
| --- | --- | --- | --- |
| **Relaxed processing time (doubled N1 and N2)** | **FR1 FDD** | **FR1 TDD** | **FR2 TDD** |
| RF: Antenna array | - | - | 33.0% |
| RF: Power amplifier  | 25.0% | 25.0% | 18.0% |
| RF: Filters | 10.0% | 14.7% | 8.0% |
| RF: Transceiver (including LNAs, mixer, and local oscillator) | 45.0% | 54.3% | 41.0% |
| RF: Duplexer / Switch | 20.0% | 6.0% | 0.0% |
| **RF: Total relative cost** | **100.0%** | **100.0%** | **100.0%** |
| BB: ADC / DAC | 10.0% | 9.0% | 4.0% |
| BB: FFT/IFFT | 4.0% | 4.0% | 4.0% |
| BB: Post-FFT data buffering | 10.0% | 10.0% | 11.0% |
| BB: Receiver processing block | 20.3% | 24.6% | 19.5% |
| BB: LDPC decoding | 6.6% | 5.9% | 5.9% |
| BB: HARQ buffer | 14.0% | 12.0% | 11.0% |
| BB: DL control processing & decoder | 4.1% | 3.3% | 4.0% |
| BB: Synchronization / cell search block | 9.0% | 9.0% | 7.0% |
| BB: UL processing block | 3.7% | 3.6% | 5.0% |
| BB: MIMO specific processing blocks | 8.8% | 8.8% | 17.5% |
| **BB: Total relative cost** | **90.5%** | **90.1%** | **88.9%** |
| **RF+BB: Total relative cost** | **94.3%** | **94.1%** | **94.4%** |

One source provided estimates of the cost for a device with relaxed UE processing time in terms of CSI computation time (see evaluation methodology described in clause 6.1) as summarized in Table 7.5.2-2. As can be seen in the last row for the total cost, the average estimated cost reduction is ~5% for FR1 FDD, ~4.5% for FR1 TDD, and ~6% for FR2 TDD.**Table 7.5.2-2: Estimated relative device cost for relaxed UE processing time in terms of CSI computation time**

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| --- | --- | --- | --- |
| **Relaxed processing time (doubled Z and Z’)** | **FR1 FDD** | **FR1 TDD** | **FR2 TDD** |
| RF: Antenna array | - | - | 33.0% |
| RF: Power amplifier  | 25.0% | 25.0% | 18.0% |
| RF: Filters | 10.0% | 15.0% | 8.0% |
| RF: Transceiver (including LNAs, mixer, and local oscillator) | 45.0% | 55.0% | 40.2% |
| RF: Duplexer / Switch | 20.0% | 5.0% | 0.0% |
| **RF: Total relative cost** | **100.0%** | **100.0%** | **99.2%** |
| BB: ADC / DAC | 10.0% | 9.0% | 4.0% |
| BB: FFT/IFFT | 4.0% | 4.0% | 4.0% |
| BB: Post-FFT data buffering | 10.0% | 10.0% | 11.0% |
| BB: Receiver processing block | 24.0% | 29.0% | 24.0% |
| BB: LDPC decoding | 10.0% | 9.0% | 9.0% |
| BB: HARQ buffer | 14.0% | 12.0% | 11.0% |
| BB: DL control processing & decoder | 2.5% | 2.0% | 2.5% |
| BB: Synchronization / cell search block | 9.0% | 9.0% | 7.0% |
| BB: UL processing block | 4.0% | 4.0% | 5.6% |
| BB: MIMO specific processing blocks | 4.5% | 4.5% | 9.0% |
| **BB: Total relative cost** | **92.0%** | **92.5%** | **87.1%** |
| **RF+BB: Total relative cost** | **95.2%** | **95.5%** | **93.6%** |

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**Proposal 2: Adopt the TP in section 3 of this document as baseline text for TR 38.875.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| DOCOMO | Y |  |
| vivo |  | Is it the correct understanding that Table 7.5.2-1 intends to capture the cost reduction analysis for the case with only N1/N2 relaxation (no CSI timeline relaxation), while Table 7.5.2-2 intends to capture the cost reduction analysis for the case with only CSI timeline relaxation (no N1/N2 relaxation)?  |
|  |  |  |