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 #5 for Potential UE complexity reduction features for RedCap**

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# 1 Introduction

Contributions [1] – [28] submitted to RAN1#103e AI 8.6.1 plus relevant parts from a few contributions [29] – [34] that were submitted to other agenda items under AI 8.6, as well as initial evaluation results in [35], were summarized in FL summary #1 (FLS1) in [R1-2008869](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2008869.zip).

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)   * 1st check point: 10/29 * 2nd check point: 11/4 * 3rd check point: 11/10 * Last check point 11/12 |

The previous round of this email discussion is documented in FL summary #4 (FLS4) in R1-2009394 ([Inbox](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Inbox/R1-2009394.zip), [Docs](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009394.zip)).

In this round of the email discussion, please provide input on the following:

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| * By Tuesday 10th November 03:00 UTC:   + Phase 1 proposals/questions tagged ‘Phase 1:’ (search for ‘Phase 1:’)   + Phase 2 proposals/questions tagged ‘Phase 2:’ (search for ‘Phase 2:’) |

Follow the naming convention in this example:

* *RedCapComplexityFLS4-v000.docx*
* *RedCapComplexityFLS4-v001-CompanyA.docx*
* *RedCapComplexityFLS4-v002-CompanyA-CompanyB.docx*
* *RedCapComplexityFLS4-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 *RedCapComplexityFLS4-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapComplexityFLS4-v003-CompanyB-CompanyC.checkout*
* CompanyC then has 30 minutes to upload *RedCapComplexityFLS4-v003-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.

In all file names, please use the hyphen character (not underline character) and include ‘v’ in front of the version number.

The structure of this document follows the structure in TR 38.875 V0.0.3 ([R1-2009490](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009490.zip)). The tables with device cost evaluation results in this contribution are based on [RedCapCost-v024-FL-Si02-SONY2.xlsx](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Inbox/drafts/8.6/EvaluationResults/RedCapCost/RedCapCost-v024-FL-Si02-SONY2.xlsx). They will eventually be updated with new results from the email discussion [103-e-NR-RedCap-EvaluationResults].

# 6 Evaluation methodology

## 6.1 Evaluation methodology for UE complexity reduction

Based on earlier agreements, submitted contributions and email discussion responses, the following TP can be considered.

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| For cost/complexity evaluation of UE complexity reduction techniques, the methodology used in TR 36.888 was used as a starting point.  Reference NR devices were defined as follows for FR1 FDD, FR1 TDD and FR2, respectively.   * All mandatory Rel-15 features (with or without capability signaling) * Single RAT * Operation in a single band at a time * Maximum bandwidth:   + For FR1: 100 MHz for DL and UL   + For FR2: 200 MHz for DL and UL * Antennas:   + For FR1 FDD: 2Rx/1Tx   + For FR1 TDD: 4Rx/1Tx   + For FR2: 2Rx/1Tx * Power class: PC3 * Processing time: Capability 1 * Modulation:   + For FR1: support 256QAM for DL and 64QAM for UL   + For FR2: support 64QAM for DL and 64QAM for UL * Access: Direct DL/UL access between UE and gNB   Detailed cost breakdown for the reference NR devices according to Table 6.1-1 was assumed in the study. The RF-to-baseband cost ratio was assumed to be 40:60 for an FR1 UE and 50:50 for an FR2 UE.  The study considered impacts on cost/complexity reduction from support of (single-carrier) operation in multiple RF bands, where it was assumed that support of multiple RF bands may affect the RF cost but not the baseband cost significantly.  NOTE: This study assesses, from a 3GPP standpoint, the technical feasibility of reduced-capability NR devices for industrial wireless sensors, video surveillance and wearables use cases. Given that factors outside 3GPP responsibility influence the cost of a modem/device, this study item (and this study report) cannot guarantee, or be used as a guarantee, that such modem/device will be low-cost in the market.  **Table 6.1-1: Detailed cost breakdown for the reference NR devices**   |  |  |  |  | | --- | --- | --- | --- | | **Functional block** | **FR1 FDD (2Rx)** | **FR1 TDD (4Rx)** | **FR2** | | **RF** | | | | | Antenna array for FR2 |  |  | ~33% | | Power amplifier | ~25% | ~25% | ~18% | | Filters | ~10% | ~15% | ~8% | | RF transceiver (including LNAs, mixer, and local oscillator) | ~45% | ~55% | ~41% | | Duplexer / Switch | ~20% | ~5% | ~0% | | **Baseband** | | | | | ADC / DAC | ~10% | ~9% | ~4% | | FFT/IFFT | ~4% | ~4% | ~4% | | Post-FFT data buffering | ~10% | ~10% | ~11% | | Receiver processing block | ~24% | ~29% | ~24% | | LDPC decoding | ~10% | ~9% | ~9% | | HARQ buffer | ~14% | ~12% | ~11% | | DL control processing & decoder | ~5% | ~4% | ~5% | | Synchronization / cell search block | ~9% | ~9% | ~7% | | UL processing block | ~5% | ~5% | ~7% | | MIMO specific processing blocks | ~9% | ~9% | ~18% | |

In FLS4, the responses regarding the TP for TR clause 6.1 concerned the sentence about multi-band support.

**Phase 1: Proposal 6.1-1d: Adopt the updated TP above for TR clause 6.1.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N | It should be Ok to just remove “(single-carrier)”, or revise as “non-CA” or “single carrier/cell”. The reference UE has “single band at a time” so all these are applicable. SUL in our view does not increase UE cost as long as it is semi-statically configured for a band, thus it can be viewed included in our estimate. Whether it is recommended or not should be separate from the discussion. |
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One response in Section 7.5.2 in FLS4 expressed the view that the averaging of cost estimates from different sources should be done by excluding outlier numbers. The following methods can be considered.

* Method A: Average of all values
* Method B: Average of all values except the smallest value and the largest value

**Phase 1: Question 6.1-3: Which method for averaging of cost estimates should be used?**

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| **Company** | **Method (A or B)** | **Comments** |
| Huawei, HiSilicon | None or A with addressing individual questions raised by companies | We assume the question is applicable for all techniques, not only for section 7.5.2.  We also assume in the end all results should be captured, instead of only averaged values which cannot reflects different UE implementations.  Given the above, it should be the motivation for efforts to identify/resolve discussion points/typos/mis-calcuation for completing the cost estimate. Specifically,   * + Values with large difference are possible due to different implementations, thus may not change the relevant observations, e.g.     - For Rx reduction, whether the PA will be impacted     - Whether the cost saving of Transceiver can be more than 1/3 from the reference number (i.e. 45%-> around 30%) when 1T2R->1T1R in FDD.     - If they are understood so, we can live with those as different UE implementations.   + Values with large difference are based on potential mis-calculation and potentially can lead to different observations among results, e.g.     - For FDD HD-FDD vs reference UE, when replacing a duplexer (20% cost) integrated with T/R filter inside (10% cost, similar to the Filter block outside the duplexer) by a switch, the cost saving cannot be reduced down to less than 10% due to the remains of filters inside, in order to keep 1Tx&2Rx.     - This high proportion of cost saving exceed the theoretical value that is possible based on the template, thus shall be clarified before endorsement or being used for drawing observations.   So our suggestion is:  **Method C: All values should be captured and can be used for averaging, but companies are encouraged to address individual questions/discussion points that are relevant.** |
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# 7 UE complexity reduction features

## 7.1 Introduction to UE complexity reduction features

## 7.2 Reduced number of UE Rx/Tx antennas

### 7.2.1 Description of feature

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) for TR clause 7.2.1.

### 7.2.2 Analysis of UE complexity reduction

The tables with device cost evaluation results in this contribution are based on [RedCapCost-v024-FL-Si02-SONY2.xlsx](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Inbox/drafts/8.6/EvaluationResults/RedCapCost/RedCapCost-v024-FL-Si02-SONY2.xlsx). They will eventually be updated with new results from the email discussion [103-e-NR-RedCap-EvaluationResults].

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| The estimated cost for a device with reduced number of UE Rx branches, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies, is summarized in Table 7.2.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction achieved by reducing the number of UE Rx branches are follows:   * FR1 FDD (2Rx 🡪 1Rx): ~26% * FR1 TDD (4Rx 🡪 2Rx): ~30% * FR1 TDD (4Rx 🡪 1Rx): ~46% * FR2 TDD (2Rx 🡪 1Rx): ~30%   Table 7.2.2-1 summarizes the estimated cost for a device with reduced number of Rx branches without taking reduced number of downlink MIMO layers into consideration, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies.  Table 7.2.2-2 summarizes the estimated cost for a device with reduced number of Rx branches and a corresponding reduction of the supported maximum number of downlink MIMO layers, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies.  By comparing Table 7.2.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:   * RF: Antenna array (only FR2) * RF: Filters * RF: Transceiver (including LNAs, mixer, and local oscillator) * Baseband: ADC/DAC * Baseband: FFT/IFFT * Baseband: Post-FFT data buffering * Baseband: Receiver processing block * Baseband: Synchronization/cell search block   Furthermore, all sourcing companies indicated that the RF cost savings (but not the baseband cost savings) accumulate across supported bands in both FR1 and FR2.  **Table 7.2.2-1: Estimated relative device cost for reduced number of UE Rx branches**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Reduced number of UE Rx branches** | **FR1 FDD**  **(2Rx 🡪 1Rx)** | **FR1 TDD**  **(4Rx 🡪** **2Rx)** | **FR1 TDD**  **(4Rx 🡪 1Rx)** | **FR2 TDD**  **(2Rx 🡪 1Rx)** | | RF: Antenna array | - | - | - | 18.2% | | RF: Power amplifier | 24.0% | 25.0% | 25.0% | 18.0% | | RF: Filters | 4.5% | 7.6% | 3.9% | 4.3% | | RF: Transceiver (including LNAs, mixer, and local oscillator) | 24.9% | 30.4% | 17.8% | 23.7% | | RF: Duplexer / Switch | 18.3% | 4.9% | 4.9% | 0.0% | | **RF: Total relative cost** | **71.7%** | **67.9%** | **51.6%** | **64.2%** | | BB: ADC / DAC | 6.4% | 5.3% | 3.4% | 2.4% | | BB: FFT/IFFT | 2.3% | 2.2% | 1.2% | 2.2% | | BB: Post-FFT data buffering | 5.9% | 5.6% | 3.4% | 6.4% | | BB: Receiver processing block | 13.7% | 15.7% | 9.0% | 13.3% | | BB: LDPC decoding | 9.7% | 8.7% | 8.6% | 8.6% | | BB: HARQ buffer | 13.6% | 11.6% | 11.4% | 10.5% | | BB: DL control processing & decoder | 4.9% | 4.0% | 3.9% | 4.9% | | BB: Synchronization / cell search block | 5.3% | 4.8% | 2.7% | 4.1% | | BB: UL processing block | 5.0% | 5.0% | 5.0% | 7.0% | | BB: MIMO specific processing blocks | 8.2% | 7.9% | 6.8% | 15.8% | | **BB: Total relative cost** | **75.0%** | **70.7%** | **55.5%** | **75.3%** | | **RF+BB: Total relative cost** | **73.7%** | **69.6%** | **54.0%** | **69.7%** |   **Table 7.2.2-2: Estimated relative device cost for reduced number of UE Rx branches and a corresponding reduction of the supported maximum number of MIMO layers**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Reduced number of UE Rx branches and MIMO layers** | **FR1 FDD**  **(2Rx 🡪 1Rx)** | **FR1 TDD**  **(4Rx 🡪** **2Rx)** | **FR1 TDD**  **(4Rx 🡪 1Rx)** | **FR2 TDD**  **(2Rx 🡪 1Rx)** | | RF: Antenna array | - | - | - | [TBD] | | RF: Power amplifier | [TBD] | [TBD] | [TBD] | [TBD] | | RF: Filters | [TBD] | [TBD] | [TBD] | [TBD] | | RF: Transceiver (including LNAs, mixer, and local oscillator) | [TBD] | [TBD] | [TBD] | [TBD] | | RF: Duplexer / Switch | [TBD] | [TBD] | [TBD] | [TBD] | | **RF: Total relative cost** | **[TBD]** | **[TBD]** | **[TBD]** | **[TBD]** | | BB: ADC / DAC | [TBD] | [TBD] | [TBD] | [TBD] | | BB: FFT/IFFT | [TBD] | [TBD] | [TBD] | [TBD] | | BB: Post-FFT data buffering | [TBD] | [TBD] | [TBD] | [TBD] | | BB: Receiver processing block | [TBD] | [TBD] | [TBD] | [TBD] | | BB: LDPC decoding | [TBD] | [TBD] | [TBD] | [TBD] | | BB: HARQ buffer | [TBD] | [TBD] | [TBD] | [TBD] | | BB: DL control processing & decoder | [TBD] | [TBD] | [TBD] | [TBD] | | BB: Synchronization / cell search block | [TBD] | [TBD] | [TBD] | [TBD] | | BB: UL processing block | [TBD] | [TBD] | [TBD] | [TBD] | | BB: MIMO specific processing blocks | [TBD] | [TBD] | [TBD] | [TBD] | | **BB: Total relative cost** | **[TBD]** | **[TBD]** | **[TBD]** | **[TBD]** | | **RF+BB: Total relative cost** | **[TBD]** | **[TBD]** | **[TBD]** | **[TBD]** | |

Since RAN1#103e has agreed to collect cost estimates for reduced number of Rx branches including corresponding reduction of number of MIMO layers, the TP for TR clause 7.2.2 can be updated to capture these estimates.

**Phase 1: Proposal 7.2.2-1b: Adopt the TP above as baseline text for TR clause 7.2.2, where the tables will be updated according to [103-e-NR-RedCap-EvaluationResults].**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y | It is Ok to state that “a corresponding reduction of the supported maximum number of downlink MIMO layers”, while in our estimate we will not reduce the MIMO layers in baseband, as reduction of Rx results in reduced MIMO layers of the entire UE already. The cost increment by a specialized single Layer chipset for e.g. FDD plus a two-Layer chipset for e.g. TDD, is not cost-efficient compared to a two-Layer chipset used across multiple bands, and thus not our implementation. |
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**Device size:**

In addition to reduction in cost/complexity benefits, the contributions [1, 2, 4, 5, 6, 8, 10, 12, 16, 19, 21, 28] have also highlighted that the reduction in number of UE Rx antennas is also beneficial in terms of reducing the size/form factor for devices, such as wearables in FR1. The contribution [2] has expressed the view that a RedCap technique, such as reduction of the number of antennas, shall not be considered a requirement to achieve a compact form factor for any use case. The contribution [28] has also expressed a similar view. More specifically, it is proposed in [28] to clarify that size reduction of device is neither an objective for RedCap study, nor within cost/complexity reduction study scope, and cannot be used to justify the choice of reduction mechanisms for RedCap UE.

With regards to the device size reduction in FR2, the contribution [28] has indicated that form factor consideration does not justify 1 Rx for RedCap in FR2. It is mentioned in [1] that reducing only the Rx branches has limited impact on reducing the device size in FR2. In [26], it is mentioned that in FR2 depending on the power, complexity, and form factor of the RedCap UE, 1Rx or 2 Rx may be selected.

Some companies say the device size is expected to increase with an increase in the number of supported bands [1, 4]. Such increase may depend on UE implementation and frequency band separation. [1]

Note that the following agreement was reached in RAN1#101e:

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| Agreements:   * [...] * Potential benefits in terms of reduced device size can be mentioned where applicable in the TR (e.g. in the section on reduced number of antennas), but the SI will not aim to quantify such benefits. |

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| The reduction of number of UE Rx branches, relative to that of the reference NR device, may be beneficial in terms of reducing the device size in FR1. This does not imply that a non-RedCap NR UE cannot be used in a compact or small form factor. |

**Phase 2: Proposal 7.2.2-1: Adopt the above description of the benefit of reduced number of UE Rx branches in terms of reducing the device size in FR1 as a baseline text for TR 38.875.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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Based on submitted contributions and email discussion responses, the following TP can be considered.

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| It is unclear whether the reduction of number of UE Rx branches, relative to that of the reference NR device, may be beneficial in terms of reducing the device size in FR2. This does not imply that a non-RedCap NR UE cannot be used in a compact or small form factor. |

**Phase 2: Proposal 7.2.2-1: Adopt the above description of the benefit of reduced number of UE Rx branches in terms of reducing the device size in FR2 as a baseline text for TR 38.875.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.2.3 Analysis of performance impacts

According to the SID [36],

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| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

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| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P0: Most companies have reported a loss in DL coverage/performance, either quantitatively or qualitatively, when reducing the number of Rx antennas [1, 2, 3, 4, 5, 6, 9, 11, 12, 14, 15, 16, 19, 20, 21, 22, 23, 26, 27, 28] . It is the recommendation of the FL that the discussion on quantitative values of the coverage loss and bottleneck channels be considered under AI 8.6.3.

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on coverage can be captured after further progression of the discussion under AI 8.6.3.

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| **Coverage:**  In general, degradation of downlink performance is expected when reducing the number of Rx branches, which may affect the coverage. The amount of degradation depends on the number of Rx branches. Quantitative evaluation results are provided in clause 9. |

**Phase 2: Question 7.2.3-2: Can the above observations of the impact on coverage for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P7: [1, 2, 3, 5, 12, 13, 15, 16, 18, 19, 21, 23, 24, 27, 28] has reported a loss in spectral efficiency/network capacity. In [4], it has been reported that the spectral efficiency decrease, but cell capacity (cell served throughput) increases. In [6], it has been noted that degree of spectral efficiency loss depends on the proportion of RedCap UE, traffic model and traffic load. The quantitative values of the loss can be discussed under AI 8.6.3.
* P8: [11] has reported the loss is sector/cell edge spectral efficiency when reducing the number of Rx antennas.
* P9: In [6], it is also noted that the impact can be managed by network by access control mechanism.
* P11: In [26], it is observed that for FR2, the number of users that can be supported is impacted by almost 50% if the number of UE Rx antennas is reduced from 2 to 1. It is also observed that 1 Rx antenna at the UE may be able to support a high number of users. It has been noted in [24] and [28] have also reported a reduction in the number of users supported. In [24], it has been mentioned that this aspect should be discussed under AI 8.6.3.

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on network capacity and spectral efficiency can be captured after further progression of the discussion under AI 8.6.3.

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| **Network capacity and spectral efficiency:**  A loss in network capacity and spectral efficiency is expected when reducing the number of UE Rx branches. The magnitude of the loss depends on the proportion of the RedCap UE, the traffic characteristics, as well as on the number of Rx branches. Quantitative evaluation results are provided in clause X. |

**Phase 2: Question 7.2.3-3: Can the above observations of the impact on network capacity and spectral efficiency for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P1: [1, 2, 3, 4, 5, 6, 15, 16, 18, 19, 20, 22, 23, 24, 28] have indicated that there will be negative impact on DL data rate/throughput when reducing the number of Rx antennas. The main reason is that reducing the number of Rx antennas will also reduce the number of transmission layers that can be transmitted in the DL. However, [3, 4, 14, 16, 19, 22, 24, 26] have also highlighted that in spite of the reduction in Rx antennas, the UEs will be able to fulfil the data rate requirements of most RedCap use cases (except high-end wearables in FR1), as given in the SID.

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Data rate:**  Reducing the number of Rx branches at the UE will lower the downlink peak data rate. This is due to the reduction in number of downlink MIMO layers that can be supported when the number of Rx branches is reduced.   * Reduction from 2 Rx branches to 1 Rx branch decreases the downlink peak rate by ~50%. * Reduction from 4 Rx branches to 2 Rx branches decreases the downlink peak rate by ~50%. * Reduction from 4 Rx branches to 1 Rx branch decreases the downlink peak rate by ~75%.   Despite this reduction in peak data rate, the UE will be able to sufficiently fulfil the peak data rate requirements for the RedCap uses cases.  The lower MCS that may need to be applied to compensate for the performance loss may have a negative impact on the achievable data rate. |

**Phase 2: Question 7.2.3-4: Can the above observations of the impact on data rate for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P2: In [26], it is observed that in FR2, support of 1 Rx antenna at the UE can satisfy the latency requirements for industrial wireless sensors and video surveillance cameras (with 100 MHz).
* P3: In [19], it is observed that reducing the number of receive antennas does not affect the reliability and latency in most cases. However, if the UE is in the cell-edge the latency can increase. In [1], it is highlighted that the UEs with reduced of number of UE Rx branches can sufficiently fulfil the latency and reliability requirements of all RedCap use cases.

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Latency and reliability:**  Reducing the number of UE Rx branches has limited impact on the latency in most cases. However, if the UE is near the cell edge, the latency can increase. Nevertheless, the latency requirements of RedCap use cases can be suffiently fulfilled, in both FR1 and FR2.  Reducing the number of UE Rx branches does not affect the reliability. However, in some cases, the reliability can only be maintained at the cost of downlink spectral efficiency loss. |

**Phase 2: Question 7.2.3-5: Can the above observations of the impact on latency and reliability for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P4: [4] and [16] have noted that power consumption is also saved by fewer RF chains and by less complexity of multi-antenna processing. In [6], it has been noted that the power consumption of 1 Rx UE is lower than that of a 2 Rx UE.
* P5: [1, 11, 13, 15, 19, 27, 28] have noted that although the reduction in Rx antenna can reduce power consumption in the RF and the baseband modules, due to longer reception time needed for downlink channels, the power consumption will be increased. In [1, 15], it has been highlighted that the actual impact depends on the DL traffic.
* P6: The evaluation results in [4] show that the power saving gains when reducing the number of UE Rx antennas from 2 to 1 are about 14% for instant messaging traffic, 11% for Heartbeat traffic and 15% for VoIP traffic. In [24], it has been mentioned that more evaluations are needed to understand the impact on overall power consumption due to lower consumption in RF/baseband modules and longer reception time.

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **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 number of RF chains and the reduction in the complexity of multi-antenna processing. However, depending on the traffic characteristics, the average power consumption of the UE can increase or decrease. |

**Phase 2: Question 7.2.3-6: Can the above observations of the impact on power consumption for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**PDCCH blocking probability:**

* P10: [1,13, 15, 19, 23, 24, 28] have noted that there will be increase in PDCCH blocking probability. This is due to use of higher ALs in order to compensate for the performance degradation from a reduced number of Rx antennas.

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **PDCCH blocking probability:**  In order to compensate for the performance degradation resulting from a reduced number of UE Rx branches, higher aggregation levels may need to be used. This can lead to increase in PDCCH blocking probability. |

**Phase 2: Question 7.2.3-7: Can the above observations of the impact on PDCCH blocking probability for reduced number of UE Rx antennas be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.2.4 Analysis of coexistence with legacy UEs

Several contributions have analyzed coexistence issues with legacy UEs. The finding can be listed as follows:

* C1: There will be coexistence impact depending on the coverage recovery solutions and other enhancements (e.g., early RedCap indication in RACH) adopted for RedCap during the initial access stage [1, 2, 5, 9, 11, 15, 21, 24]. Note that depending on the outcome of discussions taking place under AI 8.6.3, no coverage recovery may be needed to compensate for the performance loss due to reduced number of UE Rx antennas.
* C2: Blocking impacts if RedCap UE need to use higher aggregation levels for PDCCH reception [1, 2, 5, 24].
* C3: There will be coexistence issues if common DL broadcast channels (e.g., SIBx/RAR/paging) are used for both legacy UEs and RedCap UEs [1, 5, 15, 16, 24]. This is because the system treating the UEs the same will mean conservative handling of all UEs. It has also been noted in [16] that the common channels can be transmitted separately for redcap UE and normal NR UE, which can be realized by the gNB’s scheduling implementation.
* C4: RedCap UEs with reduced number of Rx antennas can coexist with legacy UEs in general [4, 11, 15, 16, 19].
* C5: The network deployment (cell planning) may be required to be adjusted [24]. It is also been mentioned in [24] that this aspect can be considered in RAN4.
* C6: 1 Rx RedCap UEs would cause significant performance degradation to legacy UEs due to coexistence needs or may cause network block for RedCap UEs accessing when the number of UEs in one cell is large [3].

**Phase 3: Question 7.2.4-1: Can the above list (C1-C6) be used as a baseline for the TP drafting for TR section 7.2.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| vivo |  | Agree to capture:   * C3, C4   Do not agree to capture:   * C5 (The aim of coverage recovery is to allow RedCap UE to access the network without changing the deployment)   To discuss further in AI 8.6.3 based on the evaluation results:   * C1, C6   To discuss further in AI 8.6.2 based on the evaluation results:   * C2 |
| ZTE | Y | C1, C2, C3 |
| Spreadtrum | Y | C1, C2, C3 |
| OPPO |  | C1,C3, C4 can be captured. |
| Samsung |  | Support to capture: C1 (only first sentence without Note), C2 (with change), C3(except the last sentence), C4  Don’t agree to capture: C5, C6 (should be discussed in RAN 2)  Additiona comment:   * C1: There will be coexistence impact depending on the coverage recovery solutions and other enhancements (e.g., early RedCap indication in RACH) adopted for RedCap during the initial access stage [1, 2, 5, 9, 11, 15, 21, 24]. Note that depending on the outcome of discussions taking place under AI 8.6.3, no coverage recovery may be needed to compensate for the performance loss due to reduced number of UE Rx antennas. * Even no coverage recovery is needed, gNB need to knows the coverage different for DL early, otherwise, it has to assume all UEs, including NR UEs, only have single Rx, so that the resource for DL transmission will increased. * C2: Blocking impacts if RedCap UE need to use higher aggregation levels for PDCCH reception [1, 2, 5, 24], especially for common search space(s) before RRC connection since all the UEs monitor the same search space. * Suggest to add text in red. * C3: There will be coexistence issues if common DL broadcast channels (e.g., SIBx/RAR/paging) are used for both legacy UEs and RedCap UEs [1, 5, 15, 16, 24]. This is because the system treating the UEs the same will mean conservative handling of all UEs. It has also been noted in [16] that the common channels can be transmitted separately for redcap UE and normal NR UE, which can be realized by the gNB’s scheduling implementation. * The last sentence need to be further discussed. With current spec, we don’t think this can be solved by gNB implementation. Separated configuration for RACH procedure and dedicated SIB is needed. |

### 7.2.5 Analysis of specification impacts

Several contributions [1, 2, 3, 4, 5, 9, 11, 12, 13, 15, 16, 19, 20, 21, 22, 23, 24, 28] also point out the specification impacts from reducing the number of UE Rx antennas. Potential RAN1 impacts depend on the techniques that may be used to compensate for the coverage and spectral efficiency loss. The extent of RAN1 impacts would also depend on the outcome of link budget analysis that is taking place under AI 8.6.3.

Some techniques highlighted in different contributions that will have RAN1 specification impacts are:

* S1: PDCCH repetition: [12, 15, 22, 24]
* S2: Additional repetitions for PDSCH: [12, 22, 24]
* S3: AL greater than 16: [11, 15, 24]
* S4: Compact DCI: [15, 24]
* S5: CSI report enhancement to improve spectral efficiency: [15]
* S6: Early indication of RedCap UE in random access: [1, 22, 15]
* S7: Group scheduling to reduce PDCCH overhead and solve PDCCH blocking issue [15]
* S8: Cross-repetition channel estimation [12]

It has been noted in [3] that depending on the performance target, e.g., peak data rate and coverage recovery, there could be no/marginal specification impacts for UEs with 2Rx (20MHz) but there would be specification impact for 1Rx UEs even with larger bandwidth (for coverage/throughput improvement).

Several contributions [1, 2, 4, 5, 13, 15, 16, 19, 20, 28] have mainly also highlighted potential RAN4 specification impacts, including RRM, receiver characteristics, demodulation performance requirements, CSI reporting requirements, RF, and procedure requirements (e.g., cell change, radio link management, beam management, etc.). It is also mentioned in [5] that RAN4 needs to evaluate and specify the new minimum number of Rx antennas for different bands. In [5], it also suggested that UL transmit antenna gain should be evaluated in RAN4 for size-limited RedCap UEs, e.g. some wearables. In [1, 28], it is indicated that the impact is more significant when reducing the number of receiver branches to 1. It has been mentioned in [1] that the impacts are manageable and comparable (at least for FR1) to the corresponding changes done for Cat M1 UEs in LTE.

In addition, [19] has indicated that there would be potential RAN2 impact due to signalling of reduced antenna capability. It has also been noted in [1] that early indication (S6) will also have RAN2 specification impacts.

**Phase 4: Question 7.2.5-1: Should RAN4 specification impacts be captured in TR 38.875 for UE antenna reduction? If yes, list the most critical ones to be captured.**

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| **Company** | **Y/N** | **Comments** |
| vivo | N | It seems all the above proposals are relevant other agenda items rather than 8.6.1, to be more specific  To discuss further in AI 8.6.3 based on the evaluation results:   * S1, S2, S3, S4, S5, S8   To discuss further in AI 8.6.5   * S6   To discuss further in AI 8.6.2   * S7 |
| ZTE | Y | RF, RRM, demodulation performance and CSI reporting requirements. |
| Panasonic | Y | RRM, demodulation performance and CSI reporting requirements |
| Spreadtrum | Y | Should consider RAN4 impact |
| OPPO |  | May have some RAN4 impact, but it shall be decided by RAN4. |
| Samsung |  | At least RRM, demo requirement is needed to support Rx reduction. If captured, it is suggested to capture RAN 4 requirement (if any) for all the techniques has potentially RAN 4 impact. We can also live with focus on RAN 4 spec inpact. |

**Phase 4: Question 7.2.5-2: Can the above list (S1-S8) be used as a baseline for the TP drafting for TR section 7.2.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| vivo | N | As commented above, S1~S8 should be discussed in the corresponding agenda items, with the potential TPs as the discussion outcome. |
| OPPO |  | S6 may be needed, but it depends on the output of the evaluation in 8.6.3. |
|  |  |  |
| Samsung |  | S1, S3, S4, can be combined as PDCCH coverage recovery. S3, S6 can be discussed in other AI.  Support to capture S5, S7,  FFS for S8, considering CE SI. |

## 7.3 UE bandwidth reduction

### 7.3.1 Description of feature

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) for TR clause 7.3.1.

### 7.3.2 Analysis of UE complexity reduction

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) as baseline text for TR clause 7.3.2.
  + Companies are invited to double-check their entries in the cost reduction spreadsheet with respect to the above comments (and to catch potential typos).
  + The table will be further updated with potential updated cost estimates.

### 7.3.3 Analysis of performance impacts

According to the SID [36],

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| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

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| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P23: The impact of reduced BW on DL and UL channels would not be large; some negligible loss may be observed due to reduced frequency diversity [1, 11, 15, 19, 27].
* P24: (FR1) UE bandwidth 20 MHz is enough to support PDCCH AL 16 in FR1 [1].
* P25: (FR2) For some use cases, increasing the max UE BW from 50 to 100 MHz may lead to an increase in mean SINR [26].
* P26: (FR2) RedCap UE may not receive AL8/16 [24].
* P27: (FR2) Due to not enough number of CCEs in the CORESET, AL 16 cannot be supported without performance loss for 50 MHz UE BW and SCS = 120 kHz [1, 26].
* P28: (FR2), Reducing the bandwidth to 50 MHz will have impact on PBCH coverage if the SSB is configured with 240 kHz SCS [1, 2, 8, 11, 27, 28].
  + The loss is assessed to be less than 1 dB [1, 11, 27].
* P29: (FR2) Reducing the bandwidth to 50 MHz will have impact on PDCCH coverage if CORESET#0 is configured to have 69.12 MHz bandwidth [1, 2, 4, 8, 16, 27, 28].
  + The loss is assessed to be ~ 1.5 – 3 dB [1, 2, 8].
* P30: (FR2) Reducing the bandwidth to 50 MHz will have impact on initial access (message 2/3/4) if CORESET#0 is configured to have 69.12 MHz bandwidth [3, 20, 23, 27].

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on coverage can be captured after further progression of the discussion under AI 8.6.3.

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| **Coverage:**  The impact of reduced bandwidth on the coverage of downlink and uplink channels would not be large, although a small loss may be observed due to reduced frequency diversity.  For PDCCH coverage, one important aspect is whether the larger aggregation levels (AL), e.g. 8 and 16, can be supported after bandwidth reduction. In FR1, UE bandwidth 20 MHz is enough for supporting AL 16 for any CORESET#0 configuration. In FR2, UE bandwidth 100 MHz is also enough for supporting AL 16 for any CORESET#0 configuration. However, reducing the UE bandwidth to 50 MHz in FR2 will have impact on PDCCH coverage when CORESET#0 is configured to have 69.12 MHz bandwidth. The loss is assessed to be ~1.5-3.0 dB. Reducing the UE bandwidth to 50 MHz will have impact on PBCH coverage if the SSB is configured with 240 kHz SCS. The loss is assessed to be within 1 dB. Furthermore, reducing the UE bandwidth to 50 MHz may also impact the coverage of initial access messages if CORESET#0 is configured to have 69.12 MHz bandwidth. |

**Phase 2: Question 7.3.3-2: Can the above observations of the impact on coverage for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P34: Bandwidth reduction will not have a significant impact on capacity and spectral efficiency [1, 11, 19].
* P35: There may be some degradation in DL and UL spectral efficiency due to the loss in frequency selective scheduling gain [15].
* P36: Network capacity may be impacted for initial access [15].
* P37: The spectral efficiency may be affected due to an increase in PDCCH blocking probability resulting from the use of a smaller CORESET bandwidth [13].
* P38: (FR2) The number of users that can be supported is impacted by almost 50% if the max UE BW is reduced from 100 MHz to 50 MHz [26].
* P39: (FR2) If dedicated channel for RedCap is introduced for supporting maximum UE bandwidth of 50 MHz, the network capacity would be impacted [20].

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on network capacity and spectral efficiency can be captured after further progression of the discussion under AI 8.6.3.

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| **Network capacity and spectral efficiency:**  Bandwidth reduction will not have a significant impact on capacity and spectral efficiency, although there may be some minor degradation due to the loss in frequency selective scheduling gain. |

**Phase 2: Question 7.3.3-3: Can the above observations of the impact on network capacity and spectral efficiency for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P1: (FR1) There is an impact on peak data rate due to BW reduction [2, 15, 19, 20, 24].
* P2: (FR1) The most demanding DL peak rate requirements (150 Mbps) can be met by 20 MHz UE BW with 2 MIMO layers [3, 4, 6, 8, 10, 12, 14, 23, 24, 26].
* P3: (FR1) The most demanding DL peak rate requirements (150 Mbps) can be met by larger than 20 MHz UE BW, e.g. 40 MHz [4, 5, 8, 12, 26].
* P4: (FR1) The most demanding UL peak rate requirements (50 Mbps) can be met by 20 MHz UE BW [8].
* P5: (FR1) Single MIMO layer, 20 MHz UE BW, and 64QAM can meet the peak bit rate requirements of most use cases [1, 2, 4, 6, 8, 14, 26].
* P6: (FR2) All the data rate requirement can be met by 50 MHz and 100 MHz BW [1, 4, 14, 24].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **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. |

**Phase 2: Question 7.3.3-4: Can the above observations of the impact on data rate for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P7: The latency requirements for industrial wireless sensors can be satisfied [1, 19].
* P8: For video surveillance cameras, the latency requirements can be satisfied [1].
* P9: For the use cases that are considered in this study, the latency associated with increased transmission time (due to the reduced bandwidth) is likely to be insignificant compared to the latency associated with the DRX functionality [19].
* P10: For larger message sizes, the latency can be increased if the large messages need to be segmented into multiple transport blocks and sent over multiple slots [19].
* P11: (FR2) The latency requirements for industrial wireless sensors may be satisfied with UE BW as small as 20 MHz. For video surveillance cameras, the latency requirements can be satisfied using 20 MHz BW for small file sizes. For larger file sizes, BW needs to be increased to ~100MHz to get more UE multiplexing capacity. 20 MHz active BWP may be enough for most cases [26].
* P12: (FR2) Bandwidth reduction results in a longer SSB/SIB1 acquisition time. However, it is not necessary to have stringent SSB acquisition requirements for RedCap use cases [1].
* P13: (FR2) To minimize the SSB/CORESET acquisition time (for multiplexing patterns 2 and 3), it may be beneficial to support 100 MHz as the max UE BW [5, 26].
* P14: (FR2) For both 50 MHz and 100 MHz bandwidth options in FR2, there will be longer SSB/SIB1 acquisition time for certain SSB and Type 0 PDCCH configurations [2, 5, 24, 25].
* P15: Longer SSB/CORESET acquisition time issue only occurs for SSB and CORESET multiplexing 2 with 240 kHz SCS SSB + 120 kHz SCS 48RB CORESET 0 if the maximum UE bandwidth is 100 MHz [5].
* P16: Reliability should not be impacted as it is envisaged that BLER targets can still be achieved at a reduced bandwidth [19].
* P17: All the RedCap bandwidth options can meet the reliability target of RedCap use cases [1].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Latency and reliability:**  All the latency and reliability requirements for the RedCap use cases can be satisfied by all the bandwidth options (20 MHz in FR1, and 50 MHz or 100 MHz in FR2)  In FR2, UE bandwidth reduction may result in a longer SSB/SIB1 acquisition time for certain configurations for SSB/CORESET multiplexing patterns 2 and 3. However, it is not necessary to have stringent SSB/SIB1 acquisition requirements for RedCap use cases. To minimize the SSB/SIB1 acquisition time, it may be beneficial to support an FR2 RedCap UE bandwidth of 100 MHz. |

**Phase 2: Question 7.3.3-5: Can the above observations of the impact on latency and reliability for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P18: UE bandwidth reduction may reduce power consumption [4, 11, 13].
* P19: Evaluation is needed to assess the effects of less RF/BB modules vs longer Rx time [19, 24].
* P20: There is no clear power consumption advantage or disadvantage due to UE bandwidth reduction. It may depend on the specific traffic scenario [1].
* P21: BW reduction has no impact on the power consumption of data channels [13].
* P22: In connected mode, when the RedCap UE operates in initial DL/UL BWP larger than maximum UE bandwidth of RedCap UEs, more power consumption would be expected due to RF retuning [5].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Power consumption:**  UE bandwidth reduction reduces power consumption of the RF and baseband modules during transmission and reception. However, depending on the traffic characteristics, the average power consumption of the UE can increase or decrease. |

**Phase 2: Question 7.3.3-6: Can the above observations of the impact on power consumption for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**PDCCH blocking probability:**

* P31: PDCCH blocking probability may be increased due to small CORESET bandwidth [13].
* P32: (FR2) Using 50 MHz instead of 100 MHz may cause considerable reduction in the PDCCH multiplexing capacity and PDCCH blocking probability [24, 26].
* P33: (FR2) PDCCH blocking probability is only slightly increased if the maximum UE bandwidth is further reduced from 100 MHz to 50 MHz [1].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **PDCCH blocking probability:**  If CORESET is configured according to the RedCap UE capability and shared by both RedCap and non-RedCap UEs, this may result in increased PDCCH blocking probability. In that case, the impact of an FR2 RedCap UE bandwidth of 50 MHz would be greater than for 100 MHz. However, if it is possible for the network to configure separate CORESET bandwidths for RedCap and non-RedCap UEs, the increase in the PDCCH blocking probability due to bandwidth reduction may be insignificant. |

**Phase 2: Question 7.3.3-7: Can the above observations of the impact on PDCCH blocking probability for UE bandwidth reduction be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### Analysis of coexistence with legacy UEs

Many contributions analyze the coexistence impacts if bandwidth reduction is introduced for RedCap UEs. The findings are summarized below. Note that some of the findings reflect different views in different contributions. Further discussions are needed to resolve these conflicting views. In the summary below, if an impact is specific to only FR1 or only FR2, it is denoted accordingly.

**General:**

* C1: (FR1) For FR1, with 20MHz bandwidth capability, Redcap UEs should be able to coexist with the legacy UE [1, 11, 16, 19].
* C2: (FR2) For FR2, with 100MHz bandwidth capability, there is no coexistence impact [1, 11, 16].
* C3: There may or may not be impacts on the coexistence with legacy UEs, depending on the cell load and the solutions for RedCap and normal UEs camped on the same cell [4].

**Initial access and initial BWP:**

* C4: There may be issues with frequency-division multiplexed RACH Occasions [24].
* C5: (FR1) For initial access in FR1, the RedCap UEs can share SSB, SIB1, other Sis, RAR and Msg4 configured for normal NR UEs [5].
* C6: (FR2) The RedCap UEs with 100 MHz maximum UE bandwidth can share SSB, SIB1, other Sis, RAR and Msg4 configured for normal NR UEs [5].
* C7: (FR2) Compared with maximum UE bandwidth of 100 MHz, to support the RedCap UEs with 50 MHz maximum UE bandwidth, more serious configuration or scheduling restrictions to normal NR UEs would be expected. It may reduce the configuration or scheduling flexibility of legacy NR UEs [5].
* C8: Separate SIB1 for RedCap devices can be configured to solve coexistence problems [9].
* C9: (FR2) Limiting the supported SCS combinations for SSB/CORESET0 may be considered [9].
* C10: (FR2) There may be issues, such as backward compatibility or configuration restriction, with SSB and CORESET0 for supporting RedCap UE with 50MHz bandwidth [2, 4, 8, 15, 17, 23, 24].
  + Two initial access procedures will have to coexist: one for ‘regular’ UEs, one for RedCap UEs [2].
* C11: (FR2) With 50MHz UE BW, there may be misalignment between Redcap UE’s receiving bandwidth and the scheduling bandwidth of PDSCH for common channel during initial access procedure [16].
* C12: Supporting RedCap UEs may result in a high load in the initial BWP [24].
* C13: RedCap UEs may not support the bandwidth of the initial UL BWP configured for normal UEs in SIB1 depending on Rel-15 cell configuration [1, 5, 8, 9, 10].
  + This impacts Msg3 [1, 5] and PUCCH for Msg4 [1].
  + A separate UL BWP for RedCap devices can be configured to solve coexistence problems [9].
* C14: For both IDLE/INACTIVE and RRC-CONNECTED modes, if RedCap UEs are offloaded to a different BWP than initial BWP, it is beneficial from UE implementation perspective to have SSB transmitted in the operating BWP for RedCap UEs [4].

**Other aspects:**

* C15: Paging capacity may be an issue [24].
* C16: (FR2) In Idle mode, if the maximum UE bandwidth of RedCap UEs is 50 MHz, paging configuration for normal NR UEs may need to be restricted if the RedCap UEs and normal NR UEs share the same paging resources [5].
* C17: PDCCH blocking probability will increase with bandwidth reduction [15].
* C18: A reduced bandwidth Redcap UE is unable to measure the PRS across a wide bandwidth [19].
* C19: Legacy UE performance might be impacted if RedCap UEs accessing the cell with full backward compatibility [17].
* C20: RedCap UEs performance might not be guaranteed if accessing the cell with full backward compatibility. [17].

**Phase 3: Question 7.3.4-1: Can the above list (C1-C20) be used as a baseline for the TP drafting for TR section 7.3.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### Analysis of specification impacts

Many contributions analyze the specification impacts if bandwidth reduction is introduced for RedCap UEs. The findings are summarized below. Note that some of the findings reflect different views in different contributions. Further discussions are needed to resolve these conflicting views. In the summary below, if an impact is specific to only FR1 or only FR2, it is denoted accordingly.

**General:**

* S1: (FR1) The specification impact is expected to be small in FR1 [11, 13, 21, 27],
* S2: (FR2) RAN1 specification impact is expected to be small for UE with 100 MHz bandwidth in FR2 [11].

**Initial access and initial BWP:**

* S3: (FR1) Rel-15 SSB and/or CORESET0 should be reused [12, 20].
* S4: (FR1) No spec impacts related to cell search, system information acquisition, RAR and Msg4 reception are expected for RedCap UEs [5].
* S5: (FR2) No spec impacts related to cell search, system information acquisition, RAR and Msg4 reception are expected for RedCap UEs with 100 MHz maximum UE bandwidth [5].
* S6: Support dedicated initial BWP or dedicated initial access procedure for RedCap [5, 7, 10, 12, 15, 16, 17, 24].
* S7: There is no need to define a dedicated initial BWP for RedCap UEs [1].
* S8: There are solutions that can be used to support RedCap UEs camping on a cell with initial DL or UL BWP bandwidth larger than the maximum UE bandwidth [1].
* S9: It is feasible to allow a RedCap UE to camp on a cell even when the initial DL or UL BWP configured in the cell is larger than the maximum UE bandwidth [1].
* S10: Support RF retuning for frequency-division multiplexed RACH Occasions or SSB/CORESET0 [1, 10, 24, 25].
* S11: During initial access procedure, if size of initial UL BWP configured for normal NR UEs is larger than the bandwidth of the RedCap UEs, Msg3 transmission of the RedCap UE can be flexibly scheduled and Msg3 hopping can be enabled if dedicated initial UL BWP is configured for the RedCap UEs [5].
* S12: For frequency-hopping Msg4 PUCCH or Msg3 PUSCH transmissions, the UE needs to frequency hop within the initial UL BWP, which may have a bandwidth larger than the maximum RedCap UE bandwidth [1].
* S13: Support configuring separated CD-SSB for RedCap UEs [17].

**Specification impact if dedicated initial BWP, dedicated initial access procedure, or dedicated BWP is introduced:**

* S14: Support initial BWP enhancement including at least one of following: multiple initial BWPs, enhancement on CORESET0, or narrow band Redcap UEs operate in a wide band system [15].
* S15: Using a separate DL BWP for SIB transmissions towards RedCap UEs [10].
* S16: Using a separate UL BWP for initial access of RedCap UEs (as well as common UL BWP shared with normal UEs) [10].
* S17: Initial BWP with non-CD SSB transmission dedicated for RedCap UEs [4].
* S18: Support dedicated BWP for RedCap [5, 7, 24].
* S19: UE switching to the dedicated BWP immediately after random access procedure may be considered to offload UEs from initial BWP [7, 26].
* S20: Mechanism for RedCap BWP switching (e.g., for switching UE from initial BWP to the dedicated BWP quickly or for other performance optimization considerations) [7, 26].
* S21: Introduce longer CORESET duration (Should be discussed in AI 8.6.3) [12, 24].
* S22: Introduce simplified BWP operation for RedCap [16].
* S23: Decouple the DL and UL BWP design for RedCap UE [16].
  + Support small DL bandwidth and large UL bandwidth.
  + Support fewer DL BWP configurations than that of UL.
* S24: Support SRS transmission or CSI report for inactive BWP(s) [15].

**System information:**

* S25: A new set of system information may be needed to indicate whether the cell supports RedCap UEs and to provide RRC configuration information [1].
* S26: System information that is needed for supporting RedCap UEs may be added as new information elements to existing SI blocks or as new SI blocks [1].
* S27: Support configuring separated resources for RedCap UEs in legacy SIB1 for RACH and paging [17].

**Paging:**

* S28: In Idle mode, dedicated paging occasions are considered for the RedCap UEs [5, 24].
* S29: The legacy paging procedure will work fine for RedCap UEs with 20 MHz bandwidth in FR1 and 50 MHz or 100 MHz bandwidth in FR2 [1].

**UE identification and capability signaling:**

* S30: Earlier identification of the RedCap UEs should be considered [5, 21].
  + S1: Identification of the RedCap UE before Msg3 transmission is needed if size of initial UL BWP configured for normal NR UEs is larger than the bandwidth of the RedCap UEs [5].
  + S1: The type of RedCap UE needs to be identified before RAR/Msg4 transmission [5].
* S31: Capability signaling defining that the UE supports a reduced bandwidth [4, 19, 21].

**RAN4:**

* S32: Most RF core requirements can be reused for supporting RedCap UE bandwidth reduction. However, certain modifications may be considered to reflect that the UE may not measure on the SSB at all times, if scheduled in other parts of the carrier [1].
* S33: There may be some minor performance impacts that need to be considered in RAN4 [19].

**Other aspects:**

* S34: In RRC\_CONNECTED, the RedCap UE can be scheduled within the maximum reception bandwidth even though the initial DL BWP configured for normal NR UEs is larger than the maximum UE bandwidth of RedCap UEs [5].
* S35: UE behavior, such as not expecting resource allocations exceeding the number of PRBs corresponding to BW limitation [2].
* S36: Support for RedCap UEs to be able to perform processing of the wider bandwidth PRS over a longer time period [19].
* S37: Study the maximum number BWPs for RedCap UEs [7].

**Additional specification impacts due to supporting 50 MHz UE in FR2:**

* S38: If the maximum UE bandwidth of RedCap UEs is 50 MHz, to guarantee the performance of RedCap UEs, dedicated common CORESET may need to be configured for system information acquisition, RAR and Msg4 reception [5].
* S39: Specification impact for reading system information [3]
* S40: Define a separate CORESET0 for RedCap UEs [27].
* S41: To allow the 240 kHz SCS SSB configuration to be used UEs with 50 MHz maximum bandwidth, the minimum guardband for SSB reception needs to be specified [1].
* S42: UE performance requirements may have to be defined for both SSB and CORESET0 in case of 50 MHz UE [11].
* S43: Enhancements are needed to compensate for potential PDCCH coverage reduction if FR2 50MHz maximum UE bandwidth is supported for initial access [9].
* S44: Reducing the UE RF bandwidth to 50MHz in FR2 may have significant specification for SSB/CORESET0 configurations using 240 kHz SCS [11, 21].
  + Potential solutions needed to address this issue require specification work
    - S45: Cell barring for the RedCap UEs. For example, the above-mentioned bandwidth is larger than the supportable maximum bandwidth of the RedCap UEs [21].
    - S46: Allowing to omit reception of channel/signal outside of its supportable maximum bandwidth, and so on [21].
    - S47: Additional or separate DL BWPs for RedCap UEs at least for some, if not all, common control [8].
    - S48: Some limitations or modifications may also need to be captured for FR2 50MHz e.g for multiplexing or retuning [2].

**Phase 4: Question 7.3.5-1: Can the above list (S1-S48) be used as a baseline for the TP drafting for TR section 7.3.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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## 7.4 Half-duplex FDD operation

### 7.4.1 Description of feature

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) as baseline text for TR clause 7.4.1.

### 7.4.2 Analysis of UE complexity reduction

The following TP in FLS4 (Proposal 7.4.2-1c) is expected to be endorsed soon.

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| The estimated cost for an HD-FDD device, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies, is summarized in Table 7.4.2-1.  For Type A HD-FDD, a high proportion of the cost saving occurs because the duplexer can be replaced with a switch and a lowpass filter.  For Type B HD-FDD, uplink and downlink can share one local oscillator, therefore, some additional saving on RF transceiver can be obtained.  By comparing Table 7.4.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributor of the cost reduction is the duplexer/switch block. Depending on the implementation, as indicated by some sourcing companies, removing the duplexer may also reduce the insertion loss in both the Rx and Tx chains and as a result, the PA power can be reduced, and the LNA sensitivity requirement can be relaxed which allows for potential UE complexity reduction.  As can be seen in the last row for the total cost, the average estimated cost reduction achieved by Type A and Type B HD-FDD is approximately ~7% and ~10%, respectively.  Furthermore, all sourcing companies indicated that the RF cost savings (but not the baseband cost savings) accumulate across supported bands.  **Table 7.4.2-1: Estimated relative device cost for an HD-FDD device**   |  |  |  | | --- | --- | --- | | **Half-duplex FDD operation** | **HD-FDD operation (Type A)** | **HD-FDD operation (Type B)** | | RF: Antenna array | - | - | | RF: Power amplifier | 24.1% | 23.9% | | RF: Filters | 10.6% | 10.7% | | RF: Transceiver (including LNAs, mixer, and local oscillator) | 44.4% | 37.6% | | RF: Duplexer / Switch | 4.8% | 4.9% | | **RF: Total relative cost** | **83.9%** | **77.1%** | | BB: ADC / DAC | 10.0% | 10.0% | | BB: FFT/IFFT | 3.8% | 3.7% | | BB: Post-FFT data buffering | 9.9% | 9.9% | | BB: Receiver processing block | 24.0% | 24.0% | | BB: LDPC decoding | 10.0% | 10.0% | | BB: HARQ buffer | 14.0% | 14.0% | | BB: DL control processing & decoder | 4.8% | 4.8% | | BB: Synchronization / cell search block | 9.0% | 9.0% | | BB: UL processing block | 4.8% | 4.8% | | BB: MIMO specific processing blocks | 9.0% | 9.0% | | **BB: Total relative cost** | **99.4%** | **99.2%** | | **RF+BB: Total relative cost** | **93.2%** | **90.3%** | |

**Device size:**

In addition to reduction in cost/complexity benefits, contribution [18] points out that HD-FDD is expected to reduce device size. Note that the following agreement was reached in RAN1#101e:

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| Agreements:   * […] * Potential benefits in terms of reduced device size can be mentioned where applicable in the TR (e.g. in the section on reduced number of antennas), but the SI will not aim to quantify such benefits. |

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| It is unclear whether the HD-FDD operation may be beneficial in terms of reducing the device size in FR1 FDD. |

**Phase 2: Proposal 7.4.2-2: Adopt the above description of the benefit of HD-FDD operation in terms of reducing the device size in FR1 FDD as a baseline text for TR 38.875.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.4.3 Analysis of performance impacts

According to the SID [36],

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| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

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| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P6: HD-FDD will not result in coverage loss and the coverage of HD-FDD UEs is expected to be at least as good as that of FD-FDD UEs [1, 4, 10, 11, 13, 15, 19, 22, 26].
* P7: HD-FDD will result in coverage loss if the same data rate needs to be maintained [3, 6].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Coverage:**  If there are no stringent requirements on latency and data rate, then HD-FDD will not result in coverage loss, otherwise a coverage loss can be expected. No RedCap use case requires both low latency and high data rate, so no coverage loss is expected for the RedCap use cases, and the coverage for HD-FDD UEs is expected to be similar as for FD-FDD UEs, or possibly even slightly better due to lower insertion loss. |

**Phase 2: Question 7.4.3-2: Can the above observations of the impact on coverage for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P17: HD-FDD results in lower spectral efficiency [4, 24].
* P18: HD-FDD has minor or no impact on spectral efficiency and capacity [1, 11, 13, 15, 19].
* P19: The lower noise figure of an HD-FDD UE leads to a moderate improvement in cell spectral efficiency and capacity [19].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Network capacity and spectral efficiency:**  HD-FDD operation has minor impact on spectral efficiency and capacity. Depending on the implementation, the potentially lower noise figure of an HD-FDD UE may lead to a moderate improvement in cell spectral efficiency and capacity. |

**Phase 2: Question 7.4.3-3: Can the above observations of the impact on network capacity and spectral efficiency for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P1: HD-FDD reduces data rate compared to FD-FDD [2, 3, 4, 6, 19, 24].
* P2: HD-FDD Redcap UEs can fulfil all the RedCap data rate requirements [1, 5, 22].
* P3: Type A HD-FDD has minor data rate and latency degradation [18].
* P4: Type B HD-FDD has a significant impact on the throughput and/or latency performance [6, 18].
* P5: It might be problematic for HD-FDD UEs to fulfill the data rate requirements of high-end wearables (e.g. 50/150 Mbps peak bitrate in UL/DL) without relying on high modulation order, MIMO and/or carrier aggregation capability [28].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Data rate:**  HD-FDD reduces data rate compared to FD-FDD, but the peak data rate requirements of RedCap use cases can still be fulfilled. |

**Phase 2: Question 7.4.3-4: Can the above observations of the impact on data rate for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P8: HD-FDD introduces longer latency than FD-HDD [3, 6, 19, 24, 28].
* P9: An HD-FDD UE in RRC\_CONNECTED can meet the 5-10 ms latency requirement for safety related sensors [1, 4].
* P10: HD-FDD has less impact on latency compared to TDD [19].
* P11: The latency requirement can be met if NR dynamic TDD is reused for HD-FDD [5].
* P12 The safety sensor use case has strict latency requirements of 5-10 ms which seems difficult for an HD-FDD device to meet [28].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Latency and reliability:**  HD-FDD introduces longer latency than FD-HDD, but the latency and reliability requirements of RedCap use cases can still be fulfilled. |

**Phase 2: Question 7.4.3-5: Can the above observations of the impact on latency and reliability for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P13: The lower insertion loss of an HD-FDD UE leads to a higher power efficiency in the transmit chain and improved power consumption when transmitting [1, 11, 19, 23].
* P14: HD-FDD has lower power consumption compared to FD-FDD [4, 10, 19, 24, 26].
  + HD-FDD has a negative impact on UE power consumption because the UE will be “on” for a longer time before being able to return to a lower power light sleep / deep sleep state. This loss is expected to be less than the gain from the lower insertion loss [19].
* P15: Compared to the reference NR modem, half duplex operation means some components can work in a reduced power state until required [13].
* P16: The impact on power consumption of HD-FDD depends on implementation [5].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Power consumption:**  The lower insertion loss of an HD-FDD UE may enable a higher power efficiency in the transmit chain and reduce power consumption. Furthermore, compared to the reference NR modem, half-duplex operation means some components can work in a reduced power state until required. However, on the other hand, HD-FDD may have a negative impact on UE average power consumption because the UE will be active for a longer time before being able to return to a lower power light sleep or deep sleep state. The impact on power consumption of HD-FDD depends on implementation and traffic characteristics. |

**Phase 2: Question 7.4.3-6: Can the above observations of the impact on power consumption for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**PDCCH blocking probability:**

* P20: HD-FDD reduces available PDCCH monitoring occasion [6].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **PDCCH blocking probability:**  HD-FDD operation may potentially reduce the available PDCCH monitoring occasions, which may potentially increase the PDCCH blocking probability. |

**Phase 2: Question 7.4.3-7: Can the above observations of the impact on PDCCH blocking probability for HD-FDD operation be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.4.4 Analysis of coexistence with legacy UEs

Many contributions analyze the coexistence impacts if HD-FDD operation is introduced for RedCap UEs. The findings are summarized below. Note that some of the findings reflect different views in different contributions. Further discussions are needed to resolve these conflicting views.

* C1: Introducing HD-FDD operation will make gNB scheduling more complicated [2, 10, 24].
* C2: HD-FDD may introduce scheduling constraints to URLLC services and may introduce issues with pre-emption indicator monitoring [3, 19, 28].
* C3: Introducing HD-FDD operation has no impact on initial access procedure as it is not likely to require simultaneous uplink and downlink transmission in legacy implementations during initial access [1, 11, 19].
* C4: Potential impact on RACH procedure to support Type B HD-FDD UE can be expected, e.g., switching time from PRACH to Msg2 for Type B HD-FDD [15, 24].
* C5: Introducing the support of Type-A HD-FDD operation will not introduce any coexistence issues with legacy UEs [1, 5].
* C6: Introducing the support of Type B HD-FDD operation may require longer time gaps between subsequent messages in the random-access procedure and may therefore introduce longer delay in the random-access procedure for legacy UEs [1].
* C7: Introducing Type B HD-FDD operation has a significant impact on the gNB scheduler [1].
* C8: HD-FDD introduces limitation on the configuration of some common RS/channels for both legacy and RedCap UEs [3].
* C9: Scheduling effectiveness is not compromised by supporting Type-A HD-FDD UE’s in paired spectrum, since each UE could switch between DL and UL at independent points in time, according to their respective scheduled or configured uplink transmissions [23].
* C10: With Type A HD FDD, only the duplexer is dropped, and the same (full-duplex) UE modem can be reused in full-duplex and half-duplex FDD UE designs, thus avoiding UE modem market fragmentation [23].

This potential impact has been moved here from Section 7.4.3 of this document where it was known as P21:

* C11: BWP adaptation may have an impact on HD-FDD operation. [7].

**Phase 3: Question 7.4.4-1: Can the above list (C1-C11) be used as a baseline for the TP drafting for TR section 7.4.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Samsung |  | Support: C3, combined C4 and C6 , C5  FFS for C1  Don’t support: C1, C2, C7, C8, C9, C10 (not belong to this AI, and don’t agree with the statement) |
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### 7.4.5 Analysis of specification impacts

Many contributions analyze the specification impacts if HD-FDD operation is introduced for RedCap UEs. The findings are summarized below. Note that some of the findings reflect different views in different contributions. Further discussions are needed to resolve these conflicting views.

* S1: RAN1 specification impact is expected to be minor [11, 17].
* S2: RAN1 specification impact is expected to be small for supporting Type A HD-FDD [1, 21].
* S3: Introducing Type B HD-FDD operation would have much more specification impacts than Type A [1].
* S4: Need to specify DL-to-UL and UL-to-DL switching time [1, 3, 4, 5, 6, 8, 12, 13, 19, 21, 22, 24].
* S5: RAN4 should decide on switching time requirements during the work item phase [19].
* S6: Need to specify HD-FDD capability signaling [1, 4, 5, 19, 21].
* S7: Need to specify how to handle DL/UL collision [1, 4, 8, 24].
* S8: For Type A HD-FDD, the guard period for DL-to-UL and UL-to-DL switching may be relaxed compared to the minimum Rx-to-Tx and Tx-to-Rx switching times defined in Rel-15 for a UE not supporting full-duplex communication [8].
* S9: The DL-to-UL and UL-to-DL switching time for a Type A HD-FDD device can reuse the same values of and specified in Table 4.3.2-3 of TS 38.211 [1].
* S10: The values of and specified in Table 4.3.2-3 of TS 38.211 cannot be used as DL-to-UL and UL-to-DL switching time for a Type B HD-FDD device [1].
* S11: Need to define applicable bands and performance requirements for HD-FDD operation [4].
* S12: RAN4 specification changes such as new reference sensitivity, RRM, and performance requirements can be expected, due to the lack of a duplexer, thus less insertion loss [1].
* S13: Thanks to the flexibility in the TDRA and HARQ timing in NR, there is less motivation to adopt features such as increasing the number of HARQ processes, multi-TB scheduling, and HARQ-ACK bundling, if Type A HD-FDD is introduced for RedCap [1].
* S14: If for unforeseeable reasons, features such as increasing the number of HARQ processes, multi-TB scheduling, and HARQ-ACK bundling, need to be introduced for enhancing the throughput for an HD-FDD UE, the specification impacts will be very significant [1].
* S15: Need to specify how DL pre-emption and UL cancellation work when HD-FDD UEs share resources with URLLC UEs [19].
* S16: Need to specify how to prioritize between eMBB traffic and URLLC traffic for the cases of (1) eMBB DL and URLLC UL and (2) eMBB UL and URLLC DL [19].
* S17: The gNB should be able to configure DL or UL durations for HD-FDD UE [12].
* S18: Type A HD-FDD operation will not impact BWP switch delay requirements [1].
* S19: Type B HD-FDD operation will require defining new BWP switch delay requirements [1].
* S20: RedCap UEs in HD-FDD mode should support BWP switching for power saving [7].

**Phase 4: Question 7.4.5-1: Can the above list (S1-S20) be used as a baseline for the TP drafting for TR section 7.4.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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## 7.5 Relaxed UE processing time

### 7.5.1 Description of feature

Based on earlier RAN1 agreements [37], the following text proposal for the TR can be considered.

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| In 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. 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.  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 FLS4, different views were expressed regarding the two last sentence in the first paragraph in the TP for TR clause 7.5.1. Perhaps one possible compromise is to keep the first of these two sentences and remove the last one.

**Phase 1: Proposal 7.5.1-2a: Adopt the TP above as baseline text for TR clause 7.5.1.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y | We can live with this. The important thing to discuss is the individual discussion points that may lead to different observations/conclusions. |
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According to guidance from the RAN1 chairman communicated in the RedCap GTW session on Tuesday 3rd November (UTC), if some companies have studied relaxed CSI computation time, this can be reflected in the TR.

**Phase 1: Question 7.5.1-3: What should be captured in the TR regarding relaxed CSI computation?**

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| **Company** | **Comments** |
| Huawei, HiSilicon | It can brefily describe what is being assumed for the presented results, as well as the results, similar to the handling of other techniques. Recommandation should be a separate discussion. One example for consideration:  “In the study, for the purpose of evaluation, there are also results for CSI computation time relaxation as below, assuming doubled Z/Z' compared to the values defined in section 5.4 TS 38.214 .  [Xxx, the sourcing results]  ” |
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### 7.5.2 Analysis of UE complexity reduction

The tables with device cost evaluation results in this contribution are based on [RedCapCost-v024-FL-Si02-SONY2.xlsx](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Inbox/drafts/8.6/EvaluationResults/RedCapCost/RedCapCost-v024-FL-Si02-SONY2.xlsx). They will eventually be updated with new results from the email discussion [103-e-NR-RedCap-EvaluationResults].

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| The estimated cost for a device with relaxed UE processing time (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 around 6% for FR1 FDD, 7% for FR1 TDD, and 6% for FR2 TDD.  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**   |  |  |  |  | | --- | --- | --- | --- | | **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% | 15.0% | 8.0% | | RF: Transceiver (including LNAs, mixer, and local oscillator) | 45.0% | 55.0% | 41.0% | | RF: Duplexer / Switch | 20.0% | 5.0% | 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 | 19.4% | 23.6% | 18.9% | | BB: LDPC decoding | 6.8% | 6.1% | 6.2% | | 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 | 8.7% | 8.7% | 6.8% | | BB: UL processing block | 3.7% | 3.5% | 5.0% | | BB: MIMO specific processing blocks | 8.5% | 8.6% | 17.0% | | **BB: Total relative cost** | **89.3%** | **88.8%** | **87.9%** | | **RF+BB: Total relative cost** | **93.6%** | **93.3%** | **93.9%** | |

In FLS4, one response in expressed the view that the averaging of cost estimates from different sources should be done by excluding outlier numbers. This aspect is treated in the new Question 6.1-3 in Section 6.1 of this document. The TP for TR clause 7.5.2 above is unchanged compared to the TP in FLS4.

**Phase 1: Proposal 7.5.2-1d:**

* **Adopt the TP above as baseline text for TR clause 7.5.2.**
  + **Companies are invited to double-check their entries in the cost reduction spreadsheet with respect to the above comments (and to catch potential typos).**
  + **The table will be further updated with potential updated cost estimates.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y | We can live with the FL hanlding of ‘DL control processing & decoder’. |
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### 7.5.3 Analysis of performance impacts

According to the SID [36],

|  |
| --- |
| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

|  |
| --- |
| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P6: Contributions [1, 2, 4, 11, 15, 24] note that no significant coverage impact is expected from a more relaxed UE processing time.

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Coverage:**  No significant coverage impact is expected from a more relaxed UE processing time. |

**Phase 2: Question 7.5.3-2: Can the above observations of the impact on coverage for UE with relaxed UE processing time be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P7: Contributions [1, 3, 4, 11, 15] note that no impact on spectral efficiency or network capacity is expected since it is up to gNB to schedule other UEs on available resources.

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Network capacity and spectral efficiency:**  No significant impact on network capacity or spectral efficiency is expected from a more relaxed UE processing time, since it is up to gNB to schedule other UEs on available resources. |

**Phase 2: Question 7.5.3-3: Can the above observations of the impact on network capacity and spectral efficiency for UE with relaxed UE processing time be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P5: Contributions [1, 2, 15, 24, 26] mention that sustained data rate may be impacted due to longer HARQ RTT because of the relaxed UE processing time.

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Data rate:**  No impact on peak data rate is expected. The sustained data rate which considers HARQ retransmissions may be impacted due to longer HARQ round-trip time caused by the relaxed UE processing time in terms of N1/N2. |

**Phase 2: Question 7.5.3-4: Can the above observations of the impact on data rate for UE with relaxed UE processing time be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P1: Contributions [1, 4, 5, 6, 9, 13, 16, 23, 24, 26, 28] mentioned the impact of relaxed UE processing time capability on latency, where [1, 4, 5, 23] provide some numerical examples of the impact on UL and DL latency for the initial transmission and different number of retransmissions.
* P2: Contributions [1, 3, 4, 5, 16, 21, 23, 24] observe that many RedCap use cases have rather relaxed latency requirements of up to 100 ms or 500 ms and thus can afford to have more relaxed UE processing time if the trade-off between cost reduction benefits and impacts is justified.
* P3: It is mentioned in several contributions [1, 2, 5, 6, 13, 23, 24, 26, 28] that for some use cases such as safety-related sensors, rather strict latency may be required, and a more relaxed UE processing may not be feasible.

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Latency and reliability:**  Relaxed UE processing time in terms of N1/N2 has impact on latency. For downlink transmission, relaxed N1 value impacts how fast HARQ-ACK feedback can be sent after the reception of PDSCH. For uplink transmission, relaxed N2 value impacts how fast PUSCH can be scheduled with respect to the UL grant. How significant the impact on latency is depends on use cases and targeted number of retransmissions. Among the RedCap use cases, some safety-related sensor use cases may have rather strict latency requirements, for which relaxed UE processing time may not be feasible. For the other RedCap use cases, the latency requirements can be fulfilled. |

**Phase 2: Question 7.5.3-5: Can the above observations of the impact on latency and reliability for UE with relaxed UE processing time be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P8: Contributions [3, 5, 13, 16] mention that relaxed processing timeline can allow for lower clock frequency and lower voltage which has an impact on the UE power consumption.
* P9: Contributions [4, 16] mentioned that power saving benefit from cross-slot scheduling can be obtained from relaxed UE processing time.
* P10: Contributions [5, 6, 11, 24, 26, 28] noted that the UE power saving gain may not be clear or may even be degraded as UE may need to stay active longer due to more relaxed UE processing time, and that it may also depend on specific implementation.
* P11: Contribution [1] notes that the NW can configure RedCap UEs to achieve power saving gain from cross-slot scheduling even if no relaxed UE processing time capability is defined.

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Power consumption:**  Relaxed UE processing time in terms of N1/N2 may allow for processing with lower clock frequency and lower voltage which has an impact on the UE power consumption. However, on the other hand, relaxed UE processing time may have a negative impact on UE average power consumption because the UE will be active for a longer time before being able to return to a lower power light sleep or deep sleep state. The impact on power consumption of HD-FDD depends on implementation and traffic characteristics. |

**Phase 2: Question 7.5.3-6: Can the above observations of the impact on power consumption for UE with relaxed UE processing time be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.5.4 Analysis of coexistence with legacy UEs

Contributions [1, 2, 23, 24] express that multiple UE processing timelines may increase complexity at the scheduler to handle and ensure coexistence with legacy UEs.

Contributions [1, 5, 8, 9, 10, 11, 15, 16, 21, 24] observe that there can be potential coexistence issues with legacy UEs during initial access/random access if a new, more relaxed UE processing time capability is introduced. For example, there exist the timing requirement for scheduling of Msg3 which depends on N1 and N2 values of UE processing time capability #1. If gNB schedules according to legacy UEs, RedCap UEs with relaxed N1/N2, if supported, may not be able to access the cell. On the other hand, if gNB considers potential presence of UEs with relaxed processing time in a cell, it would schedule according to the worst-case timing which would degrade the performance of legacy UEs. Similarly, timing of HARQ-ACK for Msg4 is also identified as a potential coexistence issue with legacy UEs in contributions [8, 9, 10, 15]. In order to support relaxed UE processing time capability during initial access, contributions [3, 8, 9, 10, 15] mention that methods for identifying RedCap UEs, e.g., before Msg3 scheduling may need to be studied.

These identified issues are listed below.

* C1: May make scheduler more complex [1, 2, 23, 24]
* C2: Identification of RedCap UEs before Msg3 may be needed [3, 8, 9, 10, 15].

This potential impact has been moved here from Section 7.5.3 of this document where it was known as P4:

* C3: Contributions [1, 4, 6, 23, 24, 26] observe negative impacts of relaxed UE processing time on scheduling complexity, especially when taking into account different scheduling timing restriction related to N1/N2 and the fact that there already exist two UE processing time capabilities in NR.

**Phase 3: Question 7.5.4-1: Can the above list (C1-C3) be used as a baseline for the TP drafting for TR section 7.5.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.5.5 Analysis of specification impacts

Contributions [1, 2, 3, 4, 13, 15, 23, 24] mention the specification impact of defining a new relaxed UE processing time capability and new values of N1/N2. Contributions [2, 23] note that the standardization effort can be high as it requires inputs and agreement from all UE manufacturers.

Other potential impacts on scheduling timing related to the existing default TDRA tables and HARQ-ACK timing range are mentioned by contributions [5, 9, 16, 21, 24]. On the other hand, contributions [1, 3, 4] note that no specification impacts beyond new definition of relaxed UE processing time are expected unless the relaxation of N1/N2 values is too excessive.

These identified impacts are listed below.

* S1: Definition of relaxed UE processing time capability and N1/N2 values [1, 2, 3, 4, 13, 15, 23, 24]
* S2: Scheduling time related to default TDRA tables and HARQ-ACK timing range [5, 9, 16, 21, 24]

**Phase 4: Question 7.5.5-1: Can the above list (S1-S2) be used as a baseline for the TP drafting for TR section 7.5.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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## 7.6 Relaxed maximum number of MIMO layers

### 7.6.1 Description of feature

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) as baseline text for TR clause 7.6.1.

### 7.6.2 Analysis of UE complexity reduction

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) as baseline text for TR clause 7.6.2.

### 7.6.3 Analysis of performance impacts

According to the SID [36],

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| --- |
| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

|  |
| --- |
| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P7: No impact on coverage [1, 4, 11, 15, 24].

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Coverage:**  Reducing the maximum number of MIMO layers does not impact the coverage. |

**Phase 2: Question 7.6.3-2: Can the above observations of the impact on the coverage for UE with relaxed maximum number of MIMO layers be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P8: [1] noted that spectral efficiency is expressed as bit rates per Hz, as reducing the maximum number of MIMO layers will decrease the peak data rates. It is expected that the maximum number of MIMO layers will degrade the spectral efficiency. However, as higher MIMO layers are scheduled when SNR is relatively high. Thus, impacts on spectral efficiency may only be observed under good channel conditions.
* P9: Cell spectral efficiency will be impacted/reduced due to reduced data rate/throughput [1, 2, 4, 5, 6, 11, 15, 24].
* P10: Capacity will be impacted/reduced due to reduced data rate [5, 24].

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on network capacity and spectral efficiency can be captured after further progression of the discussion under AI 8.6.3.

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| --- |
| **Network capacity and spectral efficiency:**  Since reducing the maximum number of MIMO layers reduces the peak data rate, it degrades the network capacity and spectral efficiency. However, the impact depends on the channel condition which affects the number of MIMO layers that are used. For example, using a high number of MIMO layers is typically considered in good channel conditions. Therefore, the reduction of maximum number of MIMO layers mainly degrades the spectral efficiency for UEs in good channel conditions. |

**Phase 2: Question 7.6.3-3: Can the above observations of the impact on the network capacity and spectral efficiency for UE with relaxed maximum number of MIMO layers be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P1: With the agreed number of MIMO layers to study, peak data rates will be reduced but it can still adequately achieve the data rate requirements for all RedCap use cases [1].
* P2: Peak/max data rate will be impacted or reduced [2, 4, 9, 15, 22, 24]. One contribution [5] further noted that data rate will be reduced by 50% and 75% when the maximum number of MIMO layers is reduced from 4 to 2 or 2 to 1 layer, and from 4 to 1 layer respectively.
* P3: Reducing to 2 MIMO layers in FR1, it can provide the capability of achieving the upper bound data rate requirements [3].

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Data rate:**  Reducing the maximum number of downlink MIMO layers will lower the downlink peak data rate.   * Reduction from 2 layers to 1 layer decreases the downlink peak rate by ~50%. * Reduction from 4 layers to 2 layers decreases the downlink peak rate by ~50%. * Reduction from 4 layers to 1 layer decreases the downlink peak rate by ~75%.   Despite this reduction in peak data rate, the UE will be able to sufficiently fulfil the peak data rate requirements for the RedCap uses cases. |

**Phase 2: Question 7.6.3-4: Can the above observations of the impact on the data rate for UE with relaxed maximum number of MIMO layers be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P4: No latency impact [24].
* P5: [1] noted that reducing the maximum number of MIMO layers may increase latency. However, the end-to-end latency requirements of RedCap use cases are relaxed (e.g. less than 100 ms for industrial wireless sensors and 500 ms for video surveillance), except the 5-10 ms requirement for safety related sensors. However, data rate of ~80 Mbps can be achieved with 20 MHz with 64QAM per MIMO layer in FR1. This allows transmitting payload up to 10 Kbytes in 1ms in layer 1 which is more than enough for small packet size expected for safety related message and enough to ensure the 5-10 ms latency requirement for safety related sensors. In FR2, it allows larger bandwidth thus higher bit rates can be achieved. Restricting the maximum number of MIMO layers can still sufficiently fulfil the latency requirements of all RedCap use cases.
* P6: Reliability should not be impacted [1, 24], as it is envisaged that BLER targets can still be achieved. [1].

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Latency and reliability:**  Reducing the number of MIMO layers does not impact the latency and reliability significantly. The reduction of the maximum number of MIMO layers is only expected to affect the achievable latency for UEs in good channel conditions. |

**Phase 2: Question 7.6.3-5: Can the above observations of the impact on the latency and reliability for UE with relaxed maximum number of MIMO layers be used as a baseline text for TR 38.875?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P11: In [1], it is noted that Reducing the maximum DL/UL modulation order and/or DL MIMO support may reduce power consumption due to reduced complexity in processing a smaller maximum TB. However, the amount of power saved may not be significant if the RedCap UEs would mostly be in RRC\_IDLE/INACTIVE states. Furthermore, reducing the maximum number of DL MIMO layers can fulfil the date rate requirements of most RedCap uses cases. In many use cases, long transmission times for large TB sizes are not expected to occur frequently for RedCap use cases. Thus, a negative impact on UE power consumption is not expected. In use cases where large TB sizes occur more often, and long transmission times might become a consequence of modulation order and MIMO layer reduction for UEs in good coverage. In such cases, there will be more pronounced negative impact on UE power consumption. In summary, the impact on UE power consumption depends on the traffic and coverage scenarios.
* P12: Reduced power consumption as higher data rate consume higher power or less processing energy is required for smaller TB sizes [1, 4, 13].
* P13: No impacts on power consumption [24].
* P14: As the number of DL antennas is kept the same, there is no power saving. And since the data rate is reduced, longer receiving time is needed to receive a DL TB. Thus, it will have negative impact on UE power saving [15].

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Power consumption:**  The reduced number of MIMO layers can result in a lower power consumption due to the reduced peak data rate and reduced complexity in processing a smaller maximum transport block size. However, depending on the traffic characteristics, the average power consumption of the UE can increase or decrease. |

**Phase 2: Question 7.6.3-6: Can the above observations of the impact on the power consumption for UE with relaxed maximum number of MIMO layers be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.6.4 Analysis of coexistence with legacy UEs

The following potential coexistence impacts were identified in the contributions:

* C1: There is no or no significant coexistence impact. [1, 2, 4, 5, 11, 15]. In [1], it is further noted that prior to the completion of initial access, it is not possible for the gNB to send the rank indication to the UE. Furthermore, a UE’s MIMO layer support could only be known to the gNB after it has retrieved the UE capability from the UE. Due to the limitation in the current specifications, legacy UEs can only be scheduled with single MIMO layer for initial access. Having a RedCap UE with reduced maximum MIMO layer support in the same network, will not affect the number of MIMO layers to be scheduled for the legacy UEs or the RedCap UEs for initial access transmissions.
* C2: Restricted to 2 MIMO layers in FR1 have no obvious coexistence issue is envisioned [3].
* C3: Implicit restrictions on TBS may impact on SIB/Msg4/Paging [24].

**Phase 3: Question 7.6.4-1: Can the above list (C1-C3) be used as a baseline for the TP drafting for TR section 7.6.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.6.5 Analysis of specification impacts

The following potential specification impacts were identified in the contributions:

* S1: UE capability indication to notify the NW of UE’s reduced capability [1, 4, 13].
* S2: Small RAN1 specification impacts [11]
* S3: Limited or no significant specification impacts [2, 15]
* S4: Reduced to 2 MIMO layers in FR1 can provide minimized specification impacts [3].
* S5: No RI and LI report are reduced for single MIMO layer support. Thus, can consider adding the descriptions with report to no RI and LI in the specifications [5].
* S6: Demodulation performance requirements for single layer may be specified in RAN4 [5].

**Phase 4: Question 7.6.5-1: Can the above list (S1-S6) be used as a baseline for the TP drafting for TR section 7.6.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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## 7.7 Relaxed maximum modulation order

### 7.7.1 Description of feature

The following TP in FLS4 (Proposal 7.7.1-1a) is expected to be endorsed soon.

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| --- |
| Relaxation of maximum mandatory modulation orders reduces complexity through reducing the amount of RF and baseband processing required.  In the study, the main options for relaxation of maximum mandatory modulation orders considered are:   * UL:   + FR1: 16QAM instead of 64QAM   + FR2: 16QAM instead of 64QAM * DL   + FR1: 64QAM instead of 256QAM   + FR2: 16QAM instead of 64QAM   The study uses a legacy NR UE as a reference. The evaluation of cost/complexity reduction is with respect to a reference UE with the maximum modulation orders shown below.   * UL:   + FR1 and FR2: 64QAM * DL   + FR1: 256QAM   + FR2: 64QAM   It is primarily assumed that these maximum modulation orders apply to data channels only. |

### 7.7.2 Analysis of UE complexity reduction

RAN1#103e agreement:

* Adopt the TP in [R1-2009393](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_103-e/Docs/R1-2009393.zip) as baseline text for TR clause 7.7.2.
  + Companies are invited to double-check their entries in the cost reduction spreadsheet with respect to the above comments (and to catch potential typos).
  + The table will be further updated with potential updated cost estimates.

### 7.7.3 Analysis of performance impacts

According to the SID [36],

|  |
| --- |
| The study includes evaluations of the impact to coverage, network capacity and spectral efficiency |

In addition, RAN1#101e made the following agreement:

|  |
| --- |
| Agreements:   * The evaluation of performance impacts includes at least peak data rate, latency and reliability (as needed for the use cases). Other performance metrics such as power consumption, spectral efficiency and PDCCH blocking probability may also be considered if appropriate for a specific technique. |

**Coverage:**

* P7: No impact on coverage [1, 4, 11, 15, 24].

Based on submitted contributions and email discussion responses, the following TP can be considered.

|  |
| --- |
| **Coverage:**  Relaxation of maximum mandatory modulation orders does not impact the coverage. |

**Phase 2: Question 7.3.3-2: Can the above observations of the impact on coverage for UE with relaxed maximum modulation orders be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Network capacity and spectral efficiency:**

* P8: [1] noted that Spectral efficiency is expressed as bit rates per Hz, as reducing the maximum modulation orders in DL/UL will decrease the peak data rates. It is expected that reducing the maximum number of MIMO layers will degrade the spectral efficiency. However, as higher MIMO layers are scheduled when SNR is relatively high. Thus, impacts on spectral efficiency may only be observed under good channel conditions.
* P9: Cell spectral efficiency will be impacted/reduced due to reduced data rate/throughput [1, 2, 4, 5, 6, 11, 15, 24].
* P10: [2] noted the impact on spectral efficiency will be substantial. [3, 11] further observed substantial cell spectral efficiency loss about 23.6% - 43.6% due to UL modulation order restriction from 64QAM to 16QAM in FR1 and about 6.43% spectral efficiency reduction due to DL modulation order restriction from 256QAM to 64QAM in FR1.
* P11: Capacity will be impacted/reduced due to reduced data rate [5, 24].

Based on submitted contributions and email discussion responses, the following TP can be considered. More text on network capacity and spectral efficiency can be captured after further progression of the discussion under AI 8.6.3.

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| --- |
| **Network capacity and spectral efficiency:**  Relaxation of maximum mandatory modulation orders will reduce both network capacity and spectral efficiency due to reduced peak data rate. |

**Phase 2: Question 7.3.3-3: Can the above observations of the impact on network capacity and spectral efficiency for UE with relaxed maximum modulation orders be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Data rate:**

* P1: With the agreed maximum modulation orders to study, peak data rates will be reduced but it can still adequately achieve the data rate requirements for all RedCap use cases [1].
* P2: Peak/max data rate will be impacted or reduced [2, 3, 4, 5, 9, 11, 15, 22, 24]. Contribution [5, 23] further noted that data rate will be reduced by ~20% and ~33% when the maximum modulation order is restricted from 256QAM to 64QAM, and from 64QAM to 16QAM respectively.

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Data rate:**  Reducing the maximum modulation orders will lower the downlink peak data rate.   * Reduction from 256QAM to 64QAM decreases the downlink peak rate by ~25%. * Reduction from 64QAM to 16QAM decreases the downlink peak rate by ~33%.   Despite this reduction in peak data rate, the UE will be able to sufficiently fulfil the peak data rate requirements for the RedCap uses cases. |

**Phase 2: Question 7.3.3-4: Can the above observations of the impact on data rate for UE with relased maximum modulation order be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Latency and reliability:**

* P3: [1] noted that restricting the DL/UL maximum modulation orders may increase latency. However, the end-to-end latency requirements of RedCap use cases are relaxed (e.g. less than 100 ms for industrial wireless sensors and 500 ms for video surveillance), except the 5-10 ms requirement for safety related sensors. Data rate of ~80 Mbps can be achieved with 20 MHz with 64QAM per MIMO layer in FR1 DL. This allows transmitting payload up to 10 Kbytes in 1ms in layer 1 which is more than enough for small packet size expected for safety related message and enough to ensure the 5-10 ms latency requirement for safety related sensors. In FR2, it allows larger bandwidth thus higher bit rates can be achieved. Restricting the DL/UL modulation orders can also sufficiently fulfil the latency requirements of all RedCap use cases.
* P4: No latency impact [24].
* P5: Slightly increased latency but acceptable for RedCap use cases [16].
* P6: Reliability should not be impacted [1, 24], as it is envisaged that BLER targets can still be achieved. [1].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Latency and reliability:**  Relaxing the maximum modulation orders may increase the latency slightly. Nevertheless, all the latency and reliability requirements for the RedCap use cases can be satisfied by all the studied options for relaxed maximum modulation orders. |

**Phase 2: Question 7.3.3-5: Can the above observations of the impact on latency and reliability for UE with relaxed maximum modulation orders used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Power consumption:**

* P12: [1] noted that Reducing the maximum DL/UL modulation order may reduce power consumption due to reduced complexity in processing a smaller maximum TB. Furthermore, reducing the DL/UL maximum modulation order may also reduce the ADC/DAC power consumption. However, the amount of power saved may not be significant if the RedCap UEs would mostly be in RRC\_IDLE/INACTIVE states. Furthermore, reducing the maximum modulation order can adequately fulfil the date rate requirements of all RedCap uses cases. In many use cases, long transmission times for large TB sizes are not expected to occur frequently for RedCap use cases. Thus, a negative impact on UE power consumption is not expected. In use cases where large TB sizes occur more often, and long transmission times might become a consequence of modulation order and MIMO layer reduction for UEs in good coverage. In such cases, there will be more pronounced negative impact on UE power consumption. In summary, the impact on UE power consumption depends on the traffic and coverage scenarios.
* P13: Reduced power consumption as higher data rate consume higher power or less processing energy is required for RF components [3, 4, 11, 13, 16].
* P14: [11] noted that power saving would be marginal.
* P15: No impacts on power consumption [24].
* P16: There will have some saving on RF part, but the receive/transmit time may be longer for high data rate case [15].

Based on submitted contributions and email discussion responses, the following TP can be considered.

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| **Power consumption:**  Relaxation of maximum modulation orders can reduce power consumption of the RF and baseband modules marginally during transmission and reception. However, the overall impact on UE power consumption depends on the traffic and coverage scenarios. |

**Phase 2: Question 7.3.3-6: Can the above observations of the impact on power consumption for UE with relaxed maximum modulation orders be used as a baseline text for TR 38.875?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.7.4 Analysis of coexistence with legacy UEs

The following potential coexistence impacts were identified in the contributions:

* C1: There is no or no significant coexistence impact. [1, 4, 9, 11, 15, 16]. Contribution [1] further noted that During initial access, for the reception of paging indication or broadcasting information (SIBx), PDSCH is not expected to be scheduled with modulation order higher than QPSK. And the scheduling information for Msg3 would be carried in PDCCH using DCI format 0\_1 which allows modulation order <= 16QAM to be sent in the DCI. From modulation order perspective, there will be no impacts by restricting the UL and/or DL maximum modulation order based on the current agreement.
* C2: For the initial access procedure, lower MCS and single layer for broadcast downlink transmission and initial uplink scheduling will be used to ensure decoding performance or poor UE channel condition. In this case, RedCap UEs are still able to finish the access procedure [9].
* C3: Implicit restrictions on TBS may impact on SIB/Msg4/Paging [24].

**Phase 3: Question 7.7.4-1: Can the above list (C1-C3) be used as a baseline for the TP drafting for TR section 7.7.4?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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### 7.7.5 Analysis of specification impacts

The following potential specification impacts were identified in the contributions:

* S1: UE capability indication to notify the NW of UE’s reduced capability [1, 4, 13]
* S2: To minimize specification impacts, there should be no optimization (only reuse) of all existing tables [2]. [5] noted that restricting to 64QAM, one possible solution is to reuse the existing 64QAM table.
* S3: Limited specification impacts [15].
* S4: Small RAN1 specification impacts [1, 4, 5, 11, 20, 24]
  + Change of DCI size, CQI table and MCS table due to restricted maximum modulation order is possible but not essential [1, 4].
  + If the maximum modulation order is restricted to 16QAM, new MCS/DCI tables are introduced [5, 20] with lower/higher spectral efficiency for UE specific allocation case [20] to achieve more scheduling flexibility. It is further noted that the standardization effort would be small if the values from Rel-15/16 tables are reused [20].
* S5: RAN4 CQI performance requirement if new CQI tables are introduced [1].

**Phase 4: Question 7.7.5-1: Can the above list (S1-S5) be used as a baseline for the TP drafting for TR section 7.7.5?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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## 7.8 Combinations of UE complexity reduction features

### 7.8.1 Description of feature combinations

Draft TPs will be provided later.

### 7.8.2 Analysis of UE complexity reduction

RAN1#103e agreements:

* For evaluating complexity reduction, to come up with a set of combinations of techniques:
  + For each case (FR1 FDD, FR1 TDD, & FR2), target up to 6 to 8 combinations
    - Detailed combinations are FFS
* For TR section 7.2.2 (on reduced number of Rx antennas), the following combinations of complexity reduction techniques are evaluated.
  1. FR1 FDD: 1 layer, 1 Rx
  2. FR1 TDD: 1 layer, 1 Rx
  3. FR1 TDD: 2 layers, 2 Rx
  4. FR2: 1 layer, 1 Rx
* For FR1 FDD, the following combinations of complexity reduction techniques are evaluated:

1. 1 layer, 1 Rx, 20 MHz
2. 1 layer, 1 Rx, 20 MHz, HD-FDD type A
3. 1 layer, 1 Rx, 20 MHz, relaxed modulations for DL & UL
4. 1 layer, 1 Rx, 20 MHz, doubled processing time for N1 & N2 only
5. 1 layer, 1 Rx, 20 MHz, relaxed modulations for DL & UL, doubled processing time for N1 & N2 only
6. 1 layer, 1 Rx, 20 MHz, relaxed modulations for DL & UL, HD-FDD type A, doubled processing time for N1 & N2 only
7. 2 layers, 2 Rx, 20 MHz, HD-FDD type A
8. 2 layers, 2 Rx, 20 MHz, doubled processing time for N1 & N2 only

* For FR1 TDD, the following combinations of complexity reduction techniques are evaluated:

1. 1 layer, 1 Rx, 20 MHz
2. 1 layer, 1 Rx, 20 MHz, relaxed modulations for DL & UL
3. 1 layer, 1 Rx, 20 MHz, doubled processing time for N1 & N2 only
4. 1 layer, 1 Rx, 20 MHz, relaxed modulations for DL & UL, doubled processing time for N1 & N2 only
5. 2 layers, 2 Rx, 20 MHz
6. 2 layers, 2 Rx, 20 MHz, relaxed modulations for DL & UL
7. 2 layers, 2 Rx, 20 MHz, doubled processing time for N1 & N2 only
8. 2 layers, 2 Rx, 20 MHz, relaxed modulations for DL & UL, doubled processing time for N1 & N2 only

* For FR2, the following combinations of complexity reduction techniques are evaluated:

1. 1 layer, 1 Rx, 100 MHz
2. 1 layer, 1 Rx, 100 MHz, relaxed modulations DL & UL
3. 1 layer, 1 Rx, 100 MHz, doubled processing time for N1 & N2 only
4. 1 layer, 1 Rx, 100 MHz, relaxed modulations DL & UL, doubled processing time for N1 & N2 only
5. 2 layers, 2 Rx, 100 MHz, relaxed modulations DL & UL
6. 2 layers, 2 Rx, 100 MHz, doubled processing time for N1 & N2 only
7. 2 layers, 2 Rx, 100 MHz, relaxed modulations DL & UL, doubled processing time for N1 & N2 only

Draft TPs will be provided once the collection of cost estimates for these combinations has progressed a bit further in the email discussion [103-e-NR-RedCap-EvaluationResults].

### 7.8.3 Analysis of performance impacts

Draft TPs will be provided later.

### 7.8.4 Analysis of coexistence with legacy UEs

Draft TPs will be provided later.

### 7.8.5 Analysis of specification impacts

Draft TPs will be provided later.

# 12 Conclusions

RAN1#103e agreements:

* Capture the recommendation that maximum bandwidth of an FR1 RedCap UE is 20 MHz during and after initial access.
  + FFS: Whether an FR1 RedCap UE can optionally support a maximum bandwidth larger than 20 MHz after initial access
* Working assumption: Support that the maximum bandwidth of an FR2 RedCap UE is 100 MHz during initial access and 100MHz after initial access.

Based on submitted input (contributions, evaluation results, email discussion responses), the following can be considered.

**Phase 1: Proposal 12-10: Confirm the working assumption: Support that the maximum bandwidth of an FR2 RedCap UE is 100 MHz during initial access and 100MHz after initial access.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y |  |
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**Phase 1: Proposal 12-20: Support that the minimum number of Rx branches of a RedCap UE is 1 for FR1 FDD bands where a non-RedCap UE is required to be equipped with a minimum of 2 Rx branches.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N | Wait. We envision that the support 2Rx&2Layers in FDD FR1 for RedCap is important. It should be decided together with the support of 1Rx&1 Layer. |
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**Phase 2: Question 12-30: Should RAN1 make a recommendation also regarding the minimum number of Rx branches of a RedCap UE for FR1 FDD bands where a non-RedCap UE is required to be equipped with a minimum of 4 Rx branches? If so, what should RAN1 recommend?**

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| **Company** | **Y/N** | **Comments** |
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**Phase 1: Proposal 12-40: Support that the minimum number of Rx branches of a RedCap UE is at least reduced from 4 to 2 for FR1 TDD bands where a non-RedCap UE is required to be equipped with a minimum of 4 Rx branches. Further reduction to 1 Rx is FFS.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y with minor | **Support that the ~~minimum~~ number of Rx branches of a RedCap UE ~~is~~ at least can be reduced from 4 to 2 for FR1 TDD bands where a non-RedCap UE is required to be equipped with a minimum of 4 Rx branches. Further reduction to 1 Rx is FFS.** |
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**Phase 2: Question 12-50: Should RAN1 make a recommendation also regarding the minimum number of Rx branches of a RedCap UE for FR1 TDD bands where a non-RedCap UE is required to be equipped with a minimum of 2 Rx branches? If so, what should RAN1 recommend?**

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| **Company** | **Y/N** | **Comments** |
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**Phase 1: Proposal 12-60: Support that the minimum number of Rx branches of an FR2 RedCap UE is 1.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Phase 1: Proposal 12-70: Support that the minimum number of supported DL MIMO layers of an FR1 FDD RedCap UE is 1.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N | Wait. We envision that the support 2Rx&2Layers in FDD FR1 for RedCap is important. It should be decided together with the support of 1Rx&1 Layer. |
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**Phase 1: Question 12-80: If RAN1 recommends 2 Rx for FR1 TDD, should RAN1 recommend 1 or 2 layers for FR1 TDD?**

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| **Company** | **1 or 2** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y | We are ok with #Layers=#Rx, i.e. 2 Layers. |
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**Phase 1: Proposal 12-90: Support that the minimum number of supported DL MIMO layers of an FR2 RedCap UE is 1.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
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**Phase 1: Proposal 12-100: Recommend that HD-FDD type B is not supported for RedCap FR1 FDD UEs.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y |  |
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**Phase 1: Proposal 12-110: Recommend that HD-FDD type A is optionally supported for RedCap FR1 FDD UEs.**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | FFS | We have some questions for better understanding the cost saving of HD-FDD type A. Unless they are clarified, we don’t see clear benefits justifying the recommendation of Type A. It is not about different UE implementations, rather, there seems to be mis-calculation in most of others results that can significantly impact the observations for cost saving (see our comments regarding Duplexer v.s filters inside/outside the duplexer).  The performance in terms of coverage, capacity, and latency etc. shuld be clear for Type A, i.e. less than FD-HDD. Of course, similar to the doubled processing time, this can be minimized by network control.  The spec impact can be depending. Current spec only support HD operation for CA/DC/SUL case where an advanced UE is assumed. With redcued capability and introducing HD-FDD to single cell FDD band, new UE behavior such as partial canclation should be defined. This is not trivial since NR supports mini-slot based scheduling, unlike LTE subframe-based where canclation can be easier.  We think FD-FDD is at least supported/recommended. |
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**Phase 1: Question 12-120: Should the TR recommend relaxed UE processing time in terms of N1/N2 for RedCap UEs?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y | It should be clear that the cost saving from doubled N1/N2 can be obvious based on different implementation (ours is 5.5% referring to reference UE, which is several $ for an IoT device!). It also has a benefit to be applicable to all FDD, TDD, FR1 and FR2. For the UE vendors do not want to implement this, capability#1 can be reused but certain choise for achieveing an even cheaper RedCap without penalty on network performance should be allowed.  The impact of doubled N1/N2 to network scheduler can be minimized by access control or early identification. Or can be comparable to the impact of other reduced capabilities, e.g. the potential support of 1Rx leads to many UEs without MIMO supported, the potential support of HD-FDD lead to TDD-like scheduling for a FDD network (which scheduler is different from TDD).  The spec impact of introducing doubled N1/N2 is expected to be small – introducing the new values only in sections for defining N1/N2 so other sections referring to N1/N2 can remain unchanged. |
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**Phase 1: Question 12-130: Should the TR recommend relaxed maximum mandatory DL modulation (from 256QAM to 64QAM) for FR1 RedCap UEs?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | Y |  |
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**Phase 1: Question 12-140: Should the TR recommend relaxed maximum mandatory UL modulation (from 64QAM to 16QAM) for FR1 RedCap UEs?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N |  |
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**Phase 1: Question 12-150: Should the TR recommend relaxed maximum mandatory DL modulation (from 64QAM to 16QAM) for FR2 RedCap UEs?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N |  |
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**Phase 1: Question 12-160: Should the TR recommend relaxed maximum mandatory UL modulation (from 64QAM to 16QAM) for FR2 RedCap UEs?**

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| **Company** | **Y/N** | **Comments or suggested revisions** |
| Huawei, HiSilicon | N |  |
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# References

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| --- | --- | --- | --- |
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| [29] | [R1-2007599](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2007599.zip) | Framework and principles for reduced capability devices | Huawei, HiSilicon |
| [30] | [R1-2007671](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2007671.zip) | Framework and Principles for Reduced Capability NR devices | vivo, Guangdong Genius |
| [31] | [R1-2008019](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2008019.zip) | Discussion on design principles and definition for RedCap device type | CMCC |
| [32] | [R1-2008101](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2008101.zip) | Discussion on Framework and Principles for Reduced Capability | Spreadtrum Communications |
| [33] | [R1-2008623](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2008623.zip) | Standardization Framework and Design Principles for NR RedCap Devices | Qualcomm Incorporated |
| [34] | [R1-2008741](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Docs/R1-2008741.zip) | Framework and principles for RedCap UE | Sequans Communications |
| [35] | [R1-2007482](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2007482.zip) | FL summary on initial collection of RedCap evaluation results | Moderator (Ericsson, Apple, Qualcomm) |
| [36] | [RP-201677](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_89e/Docs/RP-201677.zip) | Revised SID on Study on support of reduced capability NR devices | Ericsson |
| [37] | [RP-201676](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_89e/Docs/RP-201676.zip) | SR for Study on support of reduced capability NR devices | Ericsson |
| [38] | [R1-2007476](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2007476.zip) | FL summary #1 for RedCap evaluation templates | Moderator (Ericsson, Apple, Qualcomm) |