3GPP TSG-RAN WG1 Meeting #102-e Tdoc R1-20xxxxx

e-Meeting, August 17th – 28th, 2020

**Agenda Item: 8.6.1**

**Title: FL summary #1 for Potential UE complexity reduction features for RedCap**

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# 1 Introduction

This document summarizes contributions [1] – [30] which were submitted to AI 8.6.1 plus a few relevant contributions [31] – [35] that were submitted to other agenda items under AI 8.6.

This document also captures this RAN1#102-e email discussion:

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| --- |
| [102-e-NR-RedCap-01] Email discussion/approval – Johan (Ericsson)   * By 8/20 – high priority * By 8/26 – medium * By 8/28 – last check |

The questions in this document are color coded like this:

1. High priority
2. Medium priority
3. Low priority

This document contains proposals tagged FL based on the responses to the High priority questions.

# 6 Evaluation methodology

## 6.1 Evaluation methodology for UE complexity reduction

One contribution [3] proposes to add a disclaimer to the TR that the cost/complexity estimates are very rough, simplified and subjective, and that they do not account for design costs or economies of scale, and do not account many components present in real devices such as multiple band support, displays, cameras, microphones, etc., and cannot be used to guarantee low-cost in the market.

Another contribution [8] makes an observation that the methodology does not take into account economies of scale (vs. market fragmentation) amongst the cost drivers, and that this fact should be stated explicitly in Section 7.7 of TR 38.875, where combinations of reduction features are selected and assessed.

**Q 6.1-1: Can the above disclaimer from [3] and the above observation from [8] be captured in the TR?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y | The disclaimer needs to be captured before the cost/complexity estimates are included in the TR. The observation from [8] is one aspect from the disclaimer from [3]. |
| Sierra Wireless | Y |  |
| ZTE,Sanechips |  | Usually in the TR there will be a note saying the cost reduction from the tdocs are the estimates of each individual company and not the consensus of RAN1. This should address any concern in this aspects.  Anyway further elaboration will need discussion which is not necessary. |
| Panasonic | Y | We are OK to capture above. |
| vivo |  | We think it should be further discussed. This is not critical for this meeting. |
| Samsung | N | We had similar discussion in Rel-11 MTC SI. But in TS 36.888, there is no such description or observations. There is no need to capture it TR either. |
| Xiaomi | N | Actually, we don’t understand the motivation or purpose to capture the disclaimer or observation in the TR. In the MTC project, we conducted similar UE complexity analysis by using similar evaluation methodology. But there is no such disclaimer in MTC TR, why we need to capture this disclaimer in Redcap TR. |
| Huawei, HiSilicon | Y | This disclaimer and observation from [3][8] are actually pointing out an important aspect that needs to be looked at during the design of RedCap, which are also mentioned in several other contributions. In some sense or after years of commercialization, the effect of cost reduction from economies of scale can be even larger than the aspects contributed from e.g. # of Rx reduction, thus it should be our responsbility to also take this into accout when designing RedCap. This in our view is also the main motivation to have the explicity objective in SID to consider to define a UE type for RedCap.  On the other hand, it may be also benefical to capture, if possible, the effect of e.g. economies of scale based on some economics models. We are positive if this can also be done in the study phase of RedCap. |
| Nokia, NSB | Y | We are OK to capture the disclaimer and observation |
| MediaTek | Y | We feel necessary to emphasize in the disclaimer that RedCap feature combinations targeting a niche market may benefit less from economies of scale and can potentially contribute to a general fragmentation of the whole RedCap UE hardware market.  Otherwise we are fine with Futurewei’s proposal to capture the broader [3] disclaimer before the cost/complexity estimates are included in the TR. |
| Qualcomm | N | Whether or not we need to include this disclaimer in TR can be discussed at next meeting. |

Contribution [13] proposes that the number of RedCap UE hardware variants should be limited as much as possible (i.e. ideally one) to provide economies of scale, whereas contribution [15] proposes that more than one UE type should be defined to support different peak rates for different use cases. One contribution discusses whether there is any need to define explicit RedCap UE types [19]. Other contributions propose to study this further [16, 33].

One contribution [33] proposes to update the reference NR device definition to capture CA capability to evaluate reduction from actual NR devices deployed today. However, the feature lead’s understanding that the reference NR device ought to correspond to the simplest NR device that can be built today to address the targeted use cases, not necessarily the simplest actually deployed NR device.

Two contributions [12, 17] propose updated values for the assumed RF-to-baseband cost ratio, compared to the 40:60 split assumed in the LTE MTC study report TR 36.888.

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| **Contribution** | **FR1 FDD (2Rx)** | **FR1 TDD (4Rx)** | **FR2 TDD** |
| **Reference [12]** | 40:60 | 40:60 | RF cost is higher than 40%, closer to 50% or above |
| **Reference [17]** | 40:60 | 50:50 | 60:40 |

**Q 6.1-2: What RF-to-baseband cost ratio should be assumed?**

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| --- | --- | --- | --- | --- |
| **Company** | **FR1 FDD** | **FR1 TDD** | **FR2 TDD** | **Comments** |
| Example | 40:60 | 40:60 | 40:60 |  |
| FUTUREWEI |  |  |  | Not such a strong feeling as the estimates will be very rough, however very important that we agree to something. Suggest FR1 is kept the same, FR2 either the same or 50:50. |
| SONY | 40:60 | 40:60 | 50:50 | FR1 FDD: similar to 36.888  FR1 TDD: 4RX increases both RF and baseband in proportion, hence also 40:60 ratio  FR2 TDD: increased RF cost from antenna panels |
| Ericsson | 40:60 | 50:50 | 60:40 |  |
| Sierra Wireless | 40:60 | 40:60 | 50:50 |  |
| InterDigital | 40:60 | 40:60 | 50:50 |  |
| Spreadtrum | 40:60 | 40:60 | 50:50 | FR1 FDD/TDD: similar to 36.888  FR2: RF cost is higher |
| ZTE,Sanechips | 40:60 | 40:60 | 50:50 |  |
| vivo |  |  |  | We are fine with the numbers provided in [17] |
| Samsung | 40:60 | 40:60 or 50:50 | 50:50 or 60:40 | At least for FR 2, the antenna array increases the cost a lot for RF part.  For FR1 TDD and FDD, it is ok to use 40:60 in general for simplification. |
| LG | 40:60 | 40:60 | 50:50 | For FR2, either same as FR1 or 50:50 (considering the RF cost is typically higher) seems okay. |
| OPPO | 40:60 | 50:50 | 60:40 | Agree with the number proposed by Samsung |
| Xiaomi | 40:60 | 40:60 |  | Generally, for the FR1, we agree with QC’s view. 40:60 can be used for both FDD and TDD bands. For FR2, the ratio for RF part can be increased . |
| Huawei, Hisilicon | 40:60 | 40:60 | 40:60 |  |
| Sequans | 40:60 | 50:50 | 60:40 | OK also with 40:60 for FR1 TDD, and 50:50 for FR2 |
| Lenovo, Motorola Mobility | 40:60 | 50:50 | 60:40 | The assumed cost ratio is based on that RF cost increases due to e.g., higher number antenna elements. |
| Intel | 40:60 | 40:60 | 55:45 or 60:40 | To echo some of the comments above, these should be seen as rough estimates due to high sensitivity to UE implementation specifics. |
| Nokia, NSB | 40:60 | 40:60 | 50:50 |  |
| MediaTek | 40:60 | 40:60 |  | FR1 FDD and TDD have similar ratios.  The ratio for FR2 depends on several factors, and will probably be higher. |
| Qualcomm |  |  |  | The cost ratio depends heavily on UE implementation. We can agree on some ballpark numbers for the analysis. For FR1, 40:60 can be used for both FDD and TDD bands. |
| FL | For FR1 FDD, all responses propose 40:60. For FR1 TDD, most of the responses propose 40:60 and a minority propose 50:50. For FR2 TDD, about half of the responses propose 50:50 and the other responses propose 40:60 or 60:40.  Proposal:   * For cost/complexity reduction analysis, the RF-to-baseband cost ratio for an FR1 FDD UE is assumed to be 40:60. * For cost/complexity reduction analysis, the RF-to-baseband cost ratio for an FR1 TDD UE is assumed to be approximately 40:60. * For cost/complexity reduction analysis, the RF-to-baseband cost ratio for an FR2 TDD UE is assumed to be approximately 50:50. | | | |

Several contributions discuss the detailed cost breakdown for the reference NR devices either qualitatively [1, 12] or quantitatively [6, 17, 30]. For more detailed information, see the respective contributions.

|  |  |  |  |
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| **Functional block** | **FR1 FDD (2Rx)** | **FR1 TDD (4Rx)** | **FR2** |
| **RF** | | | |
| Antenna array for FR2 |  |  | 30%~35% [17] |
| Power amplifier | 25%-30% [17]  25% [6]  25% [20]  NA [30] | 28%-35% [17]  16% [6]  25% [20]  NA [30] | 15%~20% [17] |
| Filters | 5-10% [17]  10% [6]  10% [20]  NA [30] | 5%-10% [17]  13% [6]  10% [20]  NA [30] | 5%-10% [17] |
| RF transceiver (including LNAs, mixer, and local oscillator) | 40%-50% [17]  45% [6]  40% [20]  NA [30] | 45%-55% [17]  58% [6]  40% [20]  NA [30] | 40% [17] |
| Duplexer / Switch | 10-20% [17]  20% [6]  25% [20]  NA [30] | 2-3% [17]  13% [6]  25% [20]  NA [30] | 0% [17] |
| **Baseband** | | | |
| ADC / DAC | 5% [17]  10% [6]  9% [20]  NA [30] | 5% [17]  10% [6]  9% [20]  NA [30] | 5% [17] |
| FFT/IFFT | 5% [17]  5% [6]  2% [20]  ~5% [30] | 5% [17]  6% [6]  2% [20]  ~5% [30] | 5% [17] |
| Post-FFT data buffering | 10%-15% [17]  10% [6]  9% [20]  ~10% [30] | 10%-15% [17]  12% [6]  9% [20]  ~10% [30] | 10%-15% [17] |
| Receiver processing block | 20%-35% [17]  25% [6]  27% [20]  ~35% [30] | 20%-35% [17]  30% [6]  27% [20]  ~35% [30] | 20%-35% [17] |
| LDPC decoding | 5%-15% [17]  10% [6]  9% [20]  ~15% [30] | 5%-15% [17]  6% [6]  9% [20]  ~15% [30] | 5%-15% [17] |
| HARQ buffer | 10%-15% [17]  10% [6]  27% [20]  ~15% [30] | 10%-15% [17]  6% [6]  27% [20]  ~15% [30] | 10%-15% [17] |
| DL control processing & decoder | 5% [17]  5% [6]  4% [20]  NA (included in Receiver processing block) [30] | 5% [17]  3% [6]  4% [20]  NA (included in Receiver processing block) [30] | 5% [17] |
| Synchronization / cell search block | 5%-10% [17]  10% [6]  9% [20]  ~10% [30] | 5%-10% [17]  12% [6]  9% [20]  ~10% [30] | 5%-10% [17] |
| UL processing block | 5%-10% [17]  5% [6]  4% [20]  ~10% [30] | 5%-10% [17]  3% [6]  4% [20]  ~10% [30] | 5%-10% [17] |
| MIMO specific processing blocks | 10%-20% [17]  10% [6]  0% [20]  NA (included in Receiver processing block) [30] | 10%-20% [17]  12% [6]  0% [20]  NA (included in Receiver processing block) [30] | 15%-25% [17] |

**Q 6.1-3: Is there a need to define a detailed cost breakdown for the reference NR devices, or is it enough to define the RF-to-baseband cost ratios for the reference NR devices? Is the answer the same or different for FR1 and FR2?**

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| **Company** | **Comments** |
| FUTUREWEI | We agreed to 888 as a starting point, so the question should probably be reversed to see if we have consensus NOT to have detailed breakdowns. The breakdowns are useful to see how companies arrived at their estimates and avoid just stating a big number for a preferred technique and e.g. 1% for a technique that a company doesn’t like for some reason.  That said, the exact breakdowns used are not that important. 888 is the starting point, is there a very strong need to change any of the values? In fact, 888 had a range for each, it could simplify things to take a midpoint of the ranges, or slightly higher or lower such that we add to 100%. The estimates we produce can all have a “~” in front of them, and there will need to be an overall disclaimer (see 6.1-1) before we include the % number in the TR anyway. |
| SONY | Detailed cost breakdown would be useful. This can be based on the values in TR36.888 (the numbers in the table above are consistent with (or the same as) the cost breakdown in TR36.888. We think that some of the numbers in the TDD columns of the above tables need re-visiting (TDD has 4RX and so we would expect a greater proportion of cost attributed to functions such as LNAs and receiver processing / channel estimation). We also think that some of the FR2 numbers need more consideration: we expect different breakdowns between FR1 and FR2. |
| Ericsson | If agreements can be reached during RAN1#102e, having detailed cost breakdown would be beneficial to better understand cost saving impacts from certain techniques where double counting may occur. Furthermore, it would be easier to identify which components have larger complexity and thus may assist in decision-making.  However, if agreements cannot be reached during RAN1#102e, given the limited time remaining in the SI, in order to avoid spending too much time, it might be enough to define the RF-to-baseband cost ratios for the reference NR devices and other than that just rely on the existing detailed cost breakdown in 36.888 in order to ensure the study item can be finalized in Q4 2020. |
| Sierra Wireless | There is no need to have the detailed cost breakdown for the reference NR device, in either FR1 or FR2. |
| InterDigital | Agree that detailed cost breakdown would be beneficial. |
| Spreadtrum | We share the same view with Ericsson, that detailed cost breakdown would be beneficial. Maybe we can try to discuss the change of values. If we can’t reach any agreements, we can just define the RF-to-baseband cost ratios for the reference NR devices. |
| ZTE,Sanechips | It is enough to define the RF-to-baseband cost ratios for the reference NR devices for both FR1 and FR2. No further breakdown is need as in anyway they are estimate and not of much value. |
| Panasonic | We agree Ericsson’s view. |
| vivo | It will be good if at least the cost breakdown for some of the above component can be provided, for example Post-FFT data buffering, DL control processing & decoder and HARQ buffer, so that we can quantify the cost reduction benefit for reduced BW, reduced PDCCH monitoring and HARQ processes, etc. |
| Samsung | If possible, it is better to provide similar cost breakdown similar as for LTE.  Based on the agreement we made “Include antenna parts at least in the cost/complexity breakdown for FR2.”. It might be better to at least separate RF part for FR1 and FR 2. |
| LG | Cost breakdown will be useful for our discussion on the complexity reduction features for both FR1 and FR2. Given the limited time left for the study, we agree to rely on TR36.888 for the detailed cost breakdown for FR1 perhaps with some NR-specific updates such as 4Rx cases, larger bandwidth, etc. For FR2, looking at the summary in the Table above, a slight increase of the RF portion is expected, but we may still rely on the TR36.888 for the cost breakdowns within the baseband portion. If we cannot converge on cost breakdowns within the RF for FR2, then we can leave it for further study until next meeting. |
| OPPO | Share similar view as Ericsson. In addition, we don’t have clear cost reduction target, not too much time shall be spent on the cost evaluation. |
| Xiaomi | We think the cost breakdown is beneficial. And different breakdown in FR1 and FR2 is expected. |
| Huawei, HiSilicon | If there is a need to define a detailed cost breakdown for UE modem, follow the evaluation in TR36.888. FR2 should follow FR1. |
| Sequans | For both FR1 and FR2, a commonly agreed reference cost breakdown, even if it is about rough ranges, will be useful for evaluating overall cost reduction from each proposed technique. Some suggestions for improving the table:   * ADC/DAC could be also considered as part of RFIC, depending on implementation * Measurement procedures and CSI feedback have significant share in complexity of BBIC and could be consider to be added as a new line (or at least, companies should mention if it is considered either in MIMO blocks or in receiver processing block) |
| Lenovo, Motorola Mobility | If time allows, prefer detailed cost breakdown to better understand the cost saving impacts from different features. |
| Intel | Agree with the general sentiment shared in comments above. We could aim to refine the cost breakdown in 36.888, at least for FR2. For FR1, we may be able to reuse 888 for the most part. In the event of difficult convergence, relying on 36.888 and only approximating the RF:BB ratio may be a reasonable fallback for our analyses. |
| Nokia, NSB | It would be beneficial to define a detailed cost breakdown for the reference NR devices for evaluation purpose |
| MediaTek | We agree with previous views that advocate having a detailed break-down but not over-emphasizing their importance or spending too much time on a consensus. |
| Qualcomm | We agree with the comments/suggestions of Ericsson.  Due to the differences in UE implementation, there are variations in the quantities/estimates reported by companies for cost breakdown. Therefore, we think qualitative analysis should be used to identify the key/common enablers for UE complexity reduction. |
| FL | Proposal:   * Agree on a detailed cost breakdown [to be provided by the feature lead] at least for FR1 FDD based on the median of the numbers in the table above, normalized so that the sum is 100%, and then see whether the numbers for FR1 TDD and FR2 TDD need to be revisited. |

RAN1#101-e noted that “The study will consider impacts on the cost/complexity reduction from support of multiple RF bands within FR1 or FR2”.

* [1] has stated that the cost, complexity and the size of a RedCap device would scale up, although not linearly, with the number of supported RF bands within FR1 or FR2. In [1], it has also been stated that the overall relative cost/complexity reduction due to reducing number of Rx branches in a multi-band case can be expected be of the similar order as in the single-band case.
* [2] has proposed that SUL defined in Rel-15 and Rel-16 can be utilized for Rel-17 RedCap to achieve better uplink coverage, while UL CA is not proper for RedCap. The contribution has also noted that support of SUL does not directly increase the UE baseband cost, as the UE only work on one band at a given time.
* [3] has stated that the complexity reduction due to reduced number of UE Rx/Tx antennas will accumulate over multiple bands.
* [4] has stated that a wearable device supports a wide range of frequency bands, and separate antenna and Rx chain is required for bands that has large frequency separations. This will further complicate the product design with form factor limitation.
* [7] has noted that the RF complexity saving may multiply across bands when the bands are spaced sufficiently far apart that different LNAs and PAs are required. The contribution also notes that the baseband complexity saving does not replicate across multiple bands.
* [22] and [30] have estimated that a UE that has ‘support of only low-band, mid-band and high-band’ with 1 Rx antenna and 1 RF chain would provide a saving of 34% relative to a reference NR device with 8 Rx antenna and 4 RF chain.
* [33] has proposed that the reference NR device for evaluation of cost/complexity reduction should be updated to capture at least CA capability to evaluate reduction from actual NR devices deployed today.

**Q 6.1-4: Should the cost/complexity reduction from support of multiple RF bands within FR1 or FR2 be evaluated based on properly scaling up single-band evaluation results?**

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| **Company** | **Comments** |
| FUTUREWEI | The lead in “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” is not relevant to the proposal. For that statement, as a low priority some time before the end of the study, a statement can be added in the antenna reduction section that reducing antennas may reduce size, such as in low bands (e.g 700MHz).  For the proposal, we already agreed to:  Note: The study will consider impacts on the cost/complexity reduction from support of multiple RF bands within FR1 or FR2.  We do not agree to reverse that agreement. A statement as to whether the gains are mostly RF or baseband and whether gains accumulate is sufficient. No need to include examples of a scaled up value, though if helpful and others want to do that no objection. |
| SONY | The evaluation results should account for multiple RF bands. The scaling needs to be applied to individual items in the complexity breakdown table (i.e. the table in “Q 6.1-3”). E.g. if a UE support 2 bands, it might require 2 PAs, but it doesn’t require 2 LDPC blocks, hence the scaling for 2 bands would scale the PA complexity, but not the LDPC complexity. |
| Ericsson | UEs supporting multiple RF bands are expected to have approximately the same baseband cost/complexity as a single-band UE, as long as operation in a single band is taking place at a given time. Regarding RF, cost/complexity scaling depends on frequency separation, complexity-performance trade-off, and whether additional components for enabling multiband operation.  A note capturing the above points might be included in the TR. |
| Sierra Wireless | Yes, we can scale up the single-band evaluation results for multiple RF bands. |
| InterDigital | Yes. We agree that scaling needs to be applied to individual items in the complexity breakdown table. |
| ZTE,Sanechips | For simplify the evaluation we can take this assumption. |
| Panasonic | We agree Ericsson’s view. |
| vivo | As discussed in [4], instead of device cost, we are more concerned about the form factor issue due to the requirement of supporting multiple frequency bands for smart wearables. |
| Samsung | The cost reduction from support of multiple RF bands can be mentioned in genera but no need to provide quantized analysis. |
| LG | Yes, but the scaling up is applied only where applicable. Agree with Sony and Ericsson in that mostly the RF is affected from the support of multiple RF bands. It would be good to reach a consensus within this meeting on which parts are relevant for scaling up from the support of multiple RF bands. |
| OPPO | May be the RF part can be scaled with the number of supported Bands, while the baseband part is not. |
| Xiaomi | We share the same view with vivo |
| Huawei, HiSilicon | For support of multi-band, it needs firstly clarify which aspect(s) may be shared across different bands. So it is not a linear scaling up but may be estimated based on “proper” scaling (for some factors). This nevertheless needs to be proceeded based on the analysis of single-band. In summary the reduction needs to be considered based on: 1) cost reduction of single-band and 2) with considerations of resource sharing across bands. |
| Sequans | Scaling may be accurate assumption for RFIC, but for BBIC reducing the number of supported bands may not directly impact the cost. |
| Intel | Agree with Ericsson that a qualitative characterization for the expect impact on device cost in supporting multiple bands should be sufficient. |
| Nokia, NSB | We think scaling can be applied for the RF part, while the baseband part may not need scaling |
| MediaTek | We agree with Futurewei’s and Ericsson’s views. |
| Qualcomm | It was agreed in RAN1#101 that the NR reference UE supports single RF band operation, FDD (in FR1) and TDD (in FR1 and FR2). For RedCap UE, we think its BW capability should be reduced w.r.t. that of reference UE. Therefore, RedCap UE is expected to support single RF band only in both FR1 and FR2. The capability to support CA/SUL/SDL should be excluded for a RedCap UE. |
| FL | Proposal:   * In potential cost evaluations for a UE that supports multiple bands but operates in a single band at a time, it is assumed that the multi-band support affects the RF cost but not the baseband cost significantly. * In the TR, a qualitative statement may be enough, but if there are enough relevant results available at the next meeting, we can consider capturing them as well. |

# 7 UE complexity reduction features

## 7.2 Reduced number of UE Rx/Tx antennas

### 7.2.1 Description of feature

In RAN1#101-e, the following agreements were made with regards to the study on UE complexity reduction through reduced number of UE Rx/Tx antennas.

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| --- |
| Agreements:   * For FR1, study two antenna configurations for RedCap UEs, namely 1Rx/1Tx and 2Rx/1Tx. * For FR2, study two antenna configurations for RedCap UEs, namely 1Rx/1Tx and 2Rx/1Tx.   Agreements:   * [...] * Cost/complexity breakdowns can be separate for FR1 and FR2 if found beneficial. * Include antenna parts at least in the cost/complexity breakdown for FR2. * 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.   Agreements:  The reference NR device for evaluation of cost/complexity reduction supports the following:   * [...] * Operation in a single band at a time * Antennas:   + For FR1 FDD: 2Rx/1Tx   + For FR1 TDD: 4Rx/1Tx   + For FR2: 2Rx/1Tx * [...]   Note: The study will consider impacts on the cost/complexity reduction from support of multiple RF bands within FR1 or FR2. |

In the following sections, we summarize the findings/observations/proposals in various contributions under AI 8.6.1. We have also provided few questions for companies, intended as a way-forward in the SI for this complexity reduction feature.

The agreements in RAN1#101-e are on the study of reduction in Rx and Tx branches relative to the reference NR device. In FR2, however, the antenna panels can make up a considerable portion of the overall UE cost/complexity. Therefore, the reduction of antenna panels (and elements within the panels) may help to reduce UE cost. However, there would be associated performance and specification impacts. These aspects have not yet been captured in any agreements.

**Q 7.2.1-1: Should the SI study reduced number of UE (physical) antenna elements and panels in FR2?**

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| **Company** | **Comments** |
| FUTUREWEI | The question is too open ended with only one meeting to go. Either we have a specific agreement on how to handle, or just skip it. Simple ways to handle may be to increase the RF ratio as in a previous proposal. |
| SONY | We think that it is important to study FR2 RedCap UEs with reduced numbers of panels as well as panels with reduced sets of antenna elements. Reduced set of elements per panel will require a new power class (RAN4). |
| Ericsson | The UE power classes (e.g., power class 3) in FR2 are based on RAN4 requirements on EIRP (min peak, spherical coverage, etc.), which depends on number of antenna panels and number of antenna elements per panel. Therefore, a proper technical study would require RAN4 involvement. There will also be significant performance impacts, both in uplink and downlink, which are not easily captured by link-level simulations. Due to the limited time left to conclude the study item, we do not recommend the study on reduction of UE antenna panels/elements in TR 38.875.  However, we consider reducing antenna elements and panels as an effective UE cost/complexity reduction technique that fits well with stationary devices such as certain industrial sensors and surveillance cameras. It could be a potential candidate in a future RAN4 study item. |
| Sierra Wireless | Yes, if it can be done in a simple way. |
| DOCOMO | We are fine to study that aspect assuming that associated performance and specification impacts will be studied as well. |
| InterDigital | Agree with Ericsson. |
| Spreadtrum | Yes. But the reduction of antenna panels or elements within the panels will cause the reduction of antenna array gain. Whether it could be absorbed in the inefficiency of antenna should be studied in coverage recovery. |
| ZTE,Sanechips | NO. This will increase the specification complexity considerably. It is also outside the scope of the WID. |
| Sharp | Agree with FUTUREWEI. A simple way to increase the ratio of RF to BB is preferred if no specific agreement can be reached in this meeting. |
| vivo | Yes, it would be good to also include FR2 in the study. |
| Samsung | We think number of antenna panels and elements within the panels are UE implementations. Therefore, we don’t think this need to be discussed. And RAN 1 may not be the best working group to discuss it. |
| LG | Yes. |
| OPPO | Yes, **antenna reduction brings in most of the complexity and cost reduction gain.** |
| Xiaomi | We think FR1 has higher priority than FR2 for RedCap use case, so we suggest RAN1 study reduced antenna for FR1 in the first stage. |
| CMCC | We are fine to study it. |
| Huawei, Hisilicon | Due to the time limitation and the large scope of SID, the discussion of FR2 can be de-prioritized and FR1 should be focused on first. As others mentioned, no more efforts from RAN1, and RAN4 can consider the study for FR2 on antenna aspects later. |
| Sequans | Yes, SI should study this case. |
| Lenovo, Motorola Mobility | Same view with Ericsson |
| Intel | Agree with Ericsson. |
| Nokia, NSB | We don’t think we should prioritize studying reduced numbers of panels in FR2 due to time limitation and dependency on RAN4 |
| MediaTek | Can be deprioritized as argued by Ericsson, Huawei and others. |
| Qualcomm | No. We think that the possible reduction in the number of antenna elements and panels should be up to UE implementation. However, RAN4 may consider how to relax the requirements. |
| FL | The responses are split roughly 50/50 regarding whether to study reduced number of UE (physical) antenna elements and panels in FR2.  Proposal:   * The study of reduced number of UE (physical) antenna elements and panels in FR2 is not prioritized in the RedCap study item. |

### 7.2.2 Analysis of UE complexity reduction

Most contributions have pointed out that a reduced number of Rx antennas compared to a Rel-15 reference UE enables reduced complexity, e.g. in terms of the required number of RF components and a relaxation of the baseband receiver complexity. The cost/complexity reduction analysis has been done either quantitatively or qualitatively.

For FR1, the quantitative cost reductions reported in different contributions are provided in Table 1.

**Table 1: Estimation of overall relative cost saving from reduced number of UE Rx antennas in FR1**

|  |  |  |  |
| --- | --- | --- | --- |
| **Contribution** | **FR1 FDD**  **2 Rx  1 Rx** | **FR1 TDD**  **(4 Rx  2 Rx)** | **FR1 TDD**  **(4 Rx  1 Rx)** |
| [1] | 15-38% | 15-38% | 22.5-57% |
| [2] | ~20% in RF ~30% in baseband | Complexity reduction for individual RF and baseband components has been provided in Table 3 of [2] | - |
| [3] | ~30% | ~30% | - |
| [5] | Up to 50% in many baseband components/process  Reduction in RF cost | Up to 50% in many baseband components/processes  Reduction in RF cost | - |
| [6] | 31%` | 38% | 57% |
| [9] | 15-38% | - | - |
| [16] | 20%~30% | - | - |
| [17] | 33.2% | 37.5% | 56.2% |
| [20] | - | 26.8% | 37.8% |
| [22, 30] | - | 23% | 34% |
| [25] | - | 25-39% | 37-59% |
| [27] | - | factor of 2 in related parts (antennas, RF/baseband receiver chains) | - |
| [29] | 50% in RF 50% in many baseband components | 50% in RF 50% in many baseband components | - |

For FR1, the contributions [7, 8, 18, 23] have provided a qualitative analysis of cost/complexity reduction associated with different components of the RF part (e.g., Filters, RF transceiver, Duplexer /Switch, etc.) and the baseband part (e.g., ADC, FFT, Receiver processing block, decoding, buffers, Synchronization / cell search blocks, MIMO specific processing blocks, etc.). These contributions have indicated that there will be reduction in the UE complexity/cost when reducing the number of antennas. The contribution [8] have further emphasized that the complexity of transmit RF path, duplexer, frequency synthesizer, DAC, uplink baseband, initial cell search and control channel decoding are unaffected when reducing the number of receive chain, and complexity is reduced in quasi-linear proportion to the number of receiver chains in the receiver RF path.

Additionally, [19] has noted that going from 2 Rx to 1 Rx will have less impact on cost saving. The contribution [13] has stated that reducing the number of antennas will save chipset/module cost but especially if HD-FDD is supported, the cost reduction will not be significant, and that it is more economical to have one hardware variant.

For FR2, relatively fewer companies have provided cost/complexity reduction analysis, either quantitatively or qualitatively.

* [1] has stated that reducing only the Rx branches from 2 to 1 in FR2 will have limited impact on the overall cost and complexity reduction.
* [7] has stated that in FR2 reducing the number of antennas leads to complexity reduction through reduced number of antenna packages.
* [12] has noted that unlike in FR1, where ratio of RF to baseband cost was 40: 60, in FR2 the contribution of RF components to the overall cost/complexity of the reference NR UE modem is higher than 40%, closer to 50% or above.
* [17] has reported 49.64% reduction in complexity when going from for 2 Rx to 1 Rx. This is based on a 60:40 ratio of RF to baseband cost.

**Device size:**

In addition to reduction in cost/complexity benefits, the contributions [1, 2, 3, 4, 5, 7, 8, 9, 12, 15, 16, 17, 21, 25] 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 [27] has indicated that form factor consideration does not justify 1 Rx for RedCap, especially in FR2. It is mentioned in [1] that reducing only the Rx (branches) has limited impact on reducing the device size in FR2. In [29], 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.

**Q 7.2.2-1: Most companies agree that the reduced number of Rx antennas is beneficial in terms of reducing the device size. Should this benefit be captured in TR 38.875?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | As commented in 6.1-4, this is OK but is low priority. The lower carrier frequencies should be in the statement. |
| Ericsson | FR1: Yes, we agree that benefit in terms of reduced device size can be captured in the TR.  FR2: No. In our view, reducing only the Rx antennas (i.e., branches) will have limited impact on reducing the device size. We are also, however, open to receiving and take into consideration more input from UE vendors on this aspect. |
| Sierra Wireless | Yes. |
| Spreadtrum | Yes |
| ZTE,Sanechips | Yes. For both FR1 and FR2 it should be beneficial. |
| Panasonic | Yes. On FR2, as there are different views, these views can be captured. |
| vivo | Yes. |
| Samsung | Yes. |
| OPPO | Yes. For both FR1 and FR2 it should be beneficial. |
| Xiaomi | Yes. The benefit of device size should be captured in the TR for both FR1 and FR2. For wearable device, the device size is one crucial factor. |
| CMCC | Yes |
| Huawei, HiSilicon | As device size reduction is not the target, this shall not be used to justify the reduction of RedCap to e.g. 1Rx as indicated in a few contributions and is also not critically needed to be captured. It can be captured but the above information would then also be necessary to be captured together.  Also, it needs to clarify that reduction of baseband MIMO layers does not reduce the device size. |
| Sequans | Agree with Huawei – can be captured but with necessary clarifications. |
| Lenovo, Motorola Mobility | Yes |
| Intel | Yes, certainly for FR1, not necessarily for FR2. |
| Nokia, NSB | Yes |
| Qualcomm | The benefit of device size reduction should be captured in TR for RedCap UE, for both FR1 and FR2 (if any). |

### 7.2.3 Analysis of performance impacts

Concerning the impact on performance, several contributions observe that a reduced number of antennas impacts coverage, spectral efficiency, power consumption, data rate, PDCCH blocking probability, latency, reliability, and number of users supported.

The downlink coverage loss reported in the contributions are summarized in Table 2. Some contributions (e.g., [22, 23, 29]) have cited their companion paper under AI 8.6.3 for the quantitative values of coverage loss and have not included them as part of their complexity reduction paper under AI 8.6.1. Those values are, however, not included in Table 2.

**Table 2: Estimation of downlink coverage loss from reduced number of UE Rx antennas in FR1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Contribution** | **FR1 FDD**  **2 Rx  1 Rx** | **FR1 TDD**  **(4 Rx  2 Rx)** | **FR1 TDD**  **(4 Rx  1 Rx)** | **FR2**  **(2 Rx  1 Rx)** |
| [1] | SSB: 4.7 dB  PDCCH (AL16): 3.7 dB  PDSCH: 4.0 dB | SSB: 3.0 dB  PDCCH (AL16): 3.2 dB  PDSCH: 3.0 dB | SSB: 6.9 dB  PDCCH (AL16): 6.2 dB  PDSCH: 6.2 dB | SSB: 3.7 dB  PDCCH (AL16): 3.9 dB  PDSCH: 3.8 dB |
| [2] | PDCCH (AL16): 3.08 dB  PDSCH (5 Mbps): 4.34 dB  PDSCH (10 Mbps): 5.07 dB | - | - | - |
| [3] | 3-6 dB | 3-6 dB | - | - |
| [5] | - | 3 dB\* (AWGN)  \* loss in fading channels may be larger | 5.5 dB-6 dB\* (AWGN)  \* loss in fading channels may be larger | - |
| [6] | PDSCH: 4.0 dB  PDCCH (AL16): ~4.0 dB | PDSCH: 3.2 dB  PDCCH (AL16): ~3.2 dB | PDSCH: 7.2 dB  PDCCH (AL16): ~7.2 dB | - |
| [8] | PDCCH (AL16): 2.6 dB | PDCCH (AL16): 2.3 dB | PDCCH (AL16): 5.6 dB | - |
| [9] | - | SSB: 2.44 dB  PDCCH: 6.48 dB (AL1); 5.52 dB (AL2); 5.32 dB (AL4); 3.47 dB (AL8); 2.59 dB (AL6)  PDSCH: 3.85dB | SSB: 5.51 dB  PDCCH: 13.83 dB (AL1); 12.12 dB (AL2); 9.58 dB (AL4); 7.28 dB (AL8); 6.09 dB (AL6)  PDSCH: 9.83dB | - |
| [15] | - | - | >6 dB | - |
| [17] | PDCCH (AL16): ~4 dB  PDSCH: ~4dB | - | PDCCH (AL16): ~10dB  PDSCH: ~4dB | PDCCH: ~4 dB |
| [19] | PDCCH: 3.63 dB (AL=16); 4.59 dB (AL=4) | PDCCH: 2.9 dB (AL=16); 3.93 dB (AL=4) | PDCCH: 6.56 dB (AL=16); 8.52dB (AL=4) | - |
| [27] | - | - | ~7dB | - |

The above values for performance loss depend on the exact simulation assumptions used by different companies, including on channel conditions, performance requirement for different channels, etc. These are either provided in the above cited papers, or in their respective companion papers on coverage recovery. In [7, 18, 22, 23, 25], it has also been stated qualitatively that there will be coverage loss due to reduction in Rx antennas. In [4], it is noted that the impact of coverage is limited due to reduced Rx as it is shown in the coverage study that NR is UL coverage limited. In [17], it is also noted that longer acquisition time for SSB detection is expected, and that no coverage impact is expected for PUSCH due to reduction in number of Rx antennas.

Several contributions have also identified other impacts when reducing the number of Rx antennas:

**Data rate/throughput:**

* P1: [1, 2, 5, 7, 9, 18] 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.

**Latency and reliability:**

* P2: In [29], it is observed that for 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 [7], it is observed that reducing the number of receive antennas does not affect latency and reliability.

**Power consumption:**

* P4: [19] has indicated that there is less contribution to power saving for 2 Rx****1 Rx
* P5: [2] and [16] have noted that power consumption is also saved by fewer RF chains and by less complexity of multi-antenna processing
* P6: [1, 5, 6, 7, 20, 23] 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.

**Spectral efficiency/network capacity loss:**

* P7: [1, 2, 3, 4, 6, 7, 9, 13, 17, 19, 20, 23, 25], especially [2], report a loss in spectral efficiency of ~30% for 2 Rx****1 Rx.
* P8: In [6], it has been reported that loss is spectral efficiency (sector/cell edge) is 23-33% for 2 Rx****1 Rx, 39-41% for 2 Rx****2 Rx, and 53-60% for 4 Rx****1 Rx.
* P9: In [4], it is also noted that the impact can be managed by network by access control mechanism.

**PDCCH blocking probability:**

* P10: [7] and [20] 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.

**Number of users supported:**

* P11: In [29], 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.

The discussion on bottleneck channels and coverage recovery techniques to compensate for the performance loss can be taken under AI 8.6.3, and are left out of the discussion in this section. Some contributions have also noted the impact of device size limitations on potential reduced antenna efficiency. The resulting performance impact can also be studied under AI 8.6.3, and has not been considered in this section.

**Q 7.2.3-1: Does the list (P1, P2, …, P11) above capture the most important performance impacts that need to be considered for UE antenna reduction? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | The most important observation is the very large number of dB loss, especially from 4 to 1 RX. Perhaps some range in [ ] can be agreed for now, and can be revised by next meeting. Note that the table 2 is incorrect in that it says COVERAGE LOSS, which is not correct. These are performance degradations, but since the system is both UL limited and not designed to exactly match the MCL of the UL limited channel, there may not be coverage loss.  A minor point: it would be helpful, in addition to the numbers in P7/8, to say why the loss occurs. I.e., spectral efficiency will be reduced from having to use more robust MCS, repetitions, etc. |
| Ericsson | Y | Yes, beside coverage impacts and coverage recovery aspects, which are treated under the AI 8.6.3 according to the meeting agenda. |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | N | It seems the above list does not include impact for coverage, it is strange. |
| Panasonic | Y |  |
| vivo | N | We DO NOT agree with the following   * P4: From FR2 power model in TR38.840, there is 30% power saving gain from 2Rx to 1Rx, which is significant. In FR1, such power scaling model is missing and should be developed. There is no evidences in fact shown in [19] that reducing from 2Rx to 1Rx has no big contribute to power saving and cost reduction. * P6: This has to be evaluated with proper power model developed for RedCap UEs with realistic traffic model * P7/P8/P11: This has to be evaluated with realistic evaluation assumptions, in [4] we proposed the following factors to be considered for a fair comparison. We hope that in this meeting we can align the evaluation methodologies and assumptions so that companies can bring results to the next meeting. We see same discusion point is caputred in the summary of [102-e-NR-RedCap-03] section 2.3, suggest we have this discussion only in one place. * Ratio between Redcap and normal UE is not higher than 1:1 * Different traffic models for Redcap (IM traffic for wearables) and normal UEs (FTP traffic)      * Performance metrics:   + UPT to measure the performance impact to normal UEs   + Cell served throughput to measure the system capacity |
| Samsung | N | P1 (data rate) we can focus on whether the data rate can be achieved rather than provide negative impact.  We don’t think the P11 needs to be captured separated from network capability. In P11, “It is also observed that 1 Rx antenna at the UE may be able to support a high number of users.” should be removed.  P4 and P5 need to be merged and be consistent.  Coverage analysis can be added |
| OPPO | N | Share similar view as vivo |
| Xiaomi | N | Share similar view with vivo |
| CMCC | Y |  |
| Huawei, HiSilicon | Partially Y | The questions (same issue for “performance impact” in other sections) may be misleading.  The aspects (KPIs) mentioned above can be considered while whether the observations drawn from each proponent can be directly captured in the TR or not may need further discussion. Some observations are conflicting with each other. So if the question is “to be considered”, Y; but some of the ‘P’ from list (P1, P2…) including the numbers/results/observations may need more verification. Hereafter, we take the ‘P’ that are agreeable to us. |
| Sequans | Y | In addition to coverage impact of course.  For P1, final focus should be on whether target data rates can be achieved considering combination of parameters (UE antennas, MIMO, etc) – but exact impact of UE antenna reduction should be considered and analysed also independently. |
| Lenovo, Motorola Mobility | Y |  |
| Intel | Y | In terms capturing the impact, the list covers all fundamental effects.  However, it is not clear if the proposal intends to capture these points directly in TR. We assume not, but it’d be good to get a clarification. We would have concerns with capturing some of the quantitative evaluation results that may need further verifications or subject to updates to assumptions, etc. |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.2.3-2: Which of the identified performance impacts in the list above (P1, P2, …, P11) are the most critical ones to be captured in TR 38.875 for UE antenna reduction?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1, P2 |
| FUTUREWEI | Should capture:P1,P6,P7,P8,P11 (only first sentence)  No strong feeling: P4, P10  Should not capture:  P2 and P3, these are misleading as it misses the main point that latency is increased and reliability is at risk. In some cases maybe can still meet for a single RedCap UE, but in a system with many RedCap and legacy UE not clear.  P5 is part of P6  P9 is more relevant for coexistence, but not really needed in the RAN1 led part of the TR.  P11 second sentence “high number” should not be included |
| Ericsson | P1, P6, P7 (only the first part) and P10 are in our view critical to capture in the TR, and there may already be enough inputs to draft a text proposal for the TR.  Regarding P8 and P11, in our view spectral efficiency/network capacity loss is an important impact that need to be captured in the TR, but this can be quantified after evaluations have been carried out for AI 8.6.3.  Regarding P2 and P3, although important to capture latency and reliability in the TR, more inputs/evaluations are needed to identify the degree of impact. |
| Sierra Wireless | P1, P6, P7, P8, P11 |
| Spreadtrum | P1, P7, P10 |
| ZTE,Sanechips | Coverage, P1, P6, P7 |
| Panasonic | P1, P6, P7 |
| vivo | As commented in the previous question, in this meeting we suggest to discuss the SLS evaluation methodologies and assumptions so that companies can bring results to the next meeting for a fair comparison. Then we decide which are the important observations to be captured in the TR. |
| Samsung | P1, P3, P7 or P8, P9, P10 |
| OPPO | P3,P5 |
| Xiaomi | P3, P7, P9  For P1, we agree with the data rate is one metric for performance analysis. But when judging whether there is positive or negative impact, we should consider whether the requirement of data rate is fulfilled or not rather than considering whether there is data rate reduction. |
| CMCC | P1,P4,P7,P6,P10 |
| Huawei, HiSilicon | P1, P7/P8 as general requirements (data rate, SE, capacity) required in the SID; P10 can be considered for this specific aspect (as agreed can be considered for specific technique).   * Latency and reliability is important to be captured while the current observation from P2 and P3 needs further verification; * P11 is also related to capacity however the two observations it includes seems unclear. The first part is agreeable.   P4~P6 is not critical to be captured, since power consumption can also be achieved by MIMO layer adaptation as adopted in R16 power saving. |
| Sequans | P1, P6, P7/P8, P10, P11 and coverage of course |
| Lenovo, Motorola Mobility | P1, P7, P8 |
| Intel | P1, P7 or P8, P10. For latency/reliability and power consumption related observations, it may be better to have more data-points.  Also, at least for P1, P2/P3, P6, P10, appropriate clarifications or caveats need to be added w.r.t. whether the apparent degradation in performance may be acceptable with sufficient margin for the prioritized use-cases. |
| Nokia, NSB | P1, P6, P7, P8, P10, and link-level degradation (i.e. coverage loss) |
| Mediatek | P1, P6, P8, P10 |
| Qualcomm | P2, P3 and P9.  P1 and P7 can be captured, together with the performance requirements for RedCap devices. It is worth noting that the use cases of RedCap device target reduced peak data rates (and reduced spectral efficiency). How to support reduced peak rate (throughput) with reduced cost is one of the design goals of RedCap UE. For wearable devices deployed in FR1 FDD bands, reduced number of RX antennas is mandated by the device size constraint. |

### 7.2.4 Analysis of coexistence with legacy UEs

Several contributions [1, 3, 5, 7, 17] 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, 3, 17]
* C2: blocking impacts if RedCap UE need to use higher aggregation levels for PDCCH reception [3].
* C3: there will be coexistence issues if common physical channel is used for both legacy UEs and RedCap UEs [5]
* C4: No coexistence impact [7]

**Q 7.2.4-1: Does the list above (C1, C2, C3, C4) capture the most important coexistence impacts that need to be considered for UE antenna reduction? If not, what other aspects need to be added?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | No. C1 is misleading in that it implies that there is COVERAGE LOSS and that solutions and enhancements will be agreed. It also implies that these solutions themselves will eliminate the coexistence issue which is not correct.  Something like statement C3 should be a first one, that states the system treating the UEs the same will mean conservative handling of all UEs. Then a replacement for C1 can state that early identification can reduce this conservative handling, but the enhancements themselves would also have coexistence impacts (such as from partitioning the PRACH preamble space).  C2 is fine.  ‘no impact’ (C4) should not be considered in the list of impacts. |
| Ericsson | Yes |
| Spreadtrum | Yes |
| ZTE,Sanechips | Yes |
| Panasonic | Our contribution [18] mentioned RAN4 RRM performance impact. The network deployment (cell planning) corresponds to Rel.15 and 16 UE would assumes RAN4 performance of RRM, which is based on 2 Rx. If RedCap UEs would not have similar to Rel.15/16 UEs on RRM, the network deployment may be required to be adjusted. |
| vivo | We think C1 and C3 are talking about the same thing. C2 already covered in previous section, it should not be captured twice. |
| Samsung | Yes for C1,C2,  C3 should be further clarified on which common channel(s) |
| OPPO | yes |
| Xiaomi | Yes, but we think the coexistence impact could be solved |
| CMCC | Yes |
| Huawei, HiSilicon | Similar issue exists: the observations are not aligned with each other, e.g. C4 wrt others.  C1 may be too general and it actually applies to every case (whenever an enhancement is applied there may be impact to legacy.)  In general:   * with reduction of UE antenna, the system spetrum efficienct is reduced and total resource available for legacy UEs can be impacted, and * C3 |
| Sequans | Yes |
| Lenovo, Motorola Mobility | Yes |
| Intel | It seems aspects like cell spectral efficiency, user capacity, system OH aspects are combined into coexistence issues. In this regard, we tend to agree with C4.  Certainly, as in discussed in previous questions related to (P1, …P11), there would be impact to system spectral efficiency and related metrics, but these should not be seen as “coexistence issues”. Legacy and RedCap UEs with fewer antennas can still coexist just fine, just with possibly lower system spectral efficiency. Otherwise, we are capturing same effects multiple times. |
| Nokia, NSB | Yes |
| MediaTek | Not C4.  Yes for C3, C2 and C1 with some modifications as proposed by FUTUREWEI. |
| Qualcomm | Yes |

**Q 7.2.4-2: Which of the identified coexistence impacts in the list above (C1, C2, C3, C4) are the most critical ones to be captured in TR 38.875 for UE antenna reduction?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | C1, C2 |
| FUTUREWEI | Revised C3, replacement of C1, and C2 need to be included. |
| Ericsson | C2.  Depending on potential solutions, e.g., for UE identification and coverage recovery, C1 and C3 might be coexistence issues to consider. |
| Spreadtrum | C1, C2, C3 |
| ZTE,Sanechips | C1, C2,C 3. |
| Panasonic | Our view is RRM impact and the corresponding network planning can be the largest impact. |
| vivo | C1 |
| Samsung | C1,C2, |
| OPPO | C1 C3 |
| Xiaomi | C1, but what is the “coverage recovery solutions and other enhancements” is not clear to us now. |
| CMCC | C1,C2,C3 |
| Huawei, HiSilicon | Assuming SE will anyway be captured, C3 is probably the clearest one so far that needs to be considered. |
| Sequans | C1, C2, C3 |
| Lenovo, Motorola Mobility | C1, C3. |
| Intel | None at this point (see response to previous question). |
| Nokia, NSB | C1, C2, C3 |
| MediaTek | C3, C2 and C1 |
| Qualcomm | C1 and C3 can be considered.  C2 needs further study, especially when compact DCI is supported for RedCap UE. |

### 7.2.5 Analysis of specification impacts

Several contributions [1, 3, 5, 7, 17, 18, 20, 27] also point out the specification impacts from reducing the number of UE Rx antennas. These contributions have mainly highlighted potential RAN4 specification impacts, including RRM, demodulation performance requirements, CSI reporting requirements, RF, receiver sensitivity requirements, and procedure requirements (e.g., cell change, radio link management, beam management, etc.) in all RRC states. 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], it is noted that the impact is more significant, in both FR1 and FR2, when reducing the number of receiver branches to 1.

Potential RAN1 impacts depend on the techniques that may be used to compensate for the coverage and spectral efficiency loss. Some techniques highlighted in different contributions that will have RAN1 specification impacts are:

* S1: PDCCH repetition: [8, 17, 22]
* S2: Additional repetitions for PDSCH: [8, 23]
* S3: AL greater than 16: [6]
* S4: Compact DCI: [17]
* S5: CSI enhancement to improve spectral efficiency: [17]
* S6: Early indication of RedCap UE in random access: [17, 22, 25]

In addition, [7] has indicated that there would be potential RAN2 impact due to signalling of reduced antenna capability.

The discussion on bottleneck channels and coverage recovery techniques is treated under AI 8.6.3.

**Q 7.2.5-1: Does the list above (S1, S2, …, S6) capture the most important specifications impacts that need to be considered for UE antenna reduction? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | The important part to be listed here are the expected RAN4 impacts.  S1 to S6 should not be listed here. First, there may not be COVERAGE LOSS. Second, mitigating performance degradation is a different section of the TR and should not be discussed here. |
| Ericsson | Y | We do not see RAN1 specification impacts beyond potential associated coverage recovery and reduction of number of MIMO layers. |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | N | Not sure the list is complete, the most important specification impact is coverage recovery , which may include other channel/signals beside those listed here, for example, Msg2/3/4 etc |
| Panasonic | Y | We interpreted above list as the candidate techniques. If so, it covers major candidates.  We agree FUTUREWEI that the most impact would be RAN4. |
| vivo | N/A | Most of above (S1/S2/S3/S4) are coverage recovery solutions and should be discussed in the other email thread. Suggest that we avoid duplicated discussion. |
| Samsung |  | Some observations need to be further discussed.  We suggest to identify the issue first and then categorize the solutions for the issues. Some solutions can be combined. For example, S1, S3, S4 can be combined as PDCCH coverage recovery. S7 (can be combined with PDCCH coverage recovery): Longer duration CORESET.  Alternatively, we can only point to a level that “PDCCH coverage needs recovery” and point to the potential solutions in coverage recovery section in the TR. |
| OPPO | Y |  |
| Xiaomi | N | S1-S6 are coverage recovery solutions, it is not the direct spec impact resulted by Rx reduction |
| CMCC | Y | We support all the candidate techniques, but we think this can be discussed in the coverage recovery email thread. |
| Huawei, HiSilicon | N | 1) As peak data rate calculation is also captured in specifications, the reduced data rate due to reduced mandatory # of antennas/MIMO layers also has direct specification impact.  2) It may also need to be understood that, if the Rx number is reduced to 2 and the DL coverage does not need to be compensated, there may be no specification impact from S1~S2 for coverage.  3) other techniques for improvement on SE can be considered, e.g. BWP switching  4) The other potential specification impact would be the definition of UE type and the use for that in e.g. S6, as well as the reduced peak data rate. |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | N | Similar views as Samsung – the current list is “too detailed” in terms of specific candidate enhancements, which may not be prudent to get into at this stage. Better to abstract/level-up on the detailed candidates. Otherwise, we would need a much longer list that may not be helpful/insightful. |
| Nokia, NSB | Y |  |
| Qualcomm | N | RAN4 impacts are expected for reduced number of RX antennas.  As discussed in [29], the coverage recovery solutions for FR2 also include beam refinement, frequency hopping enhancement and compact L1 measurement report, which are expected to have spec impacts in RAN1.  On the other hand, there is no need to duplicate the candidate solutions for coverage recovery in “spec impacts of reduced number of UE RX antennas.” |

**Q 7.2.5-2: Which of the identified specification impacts in the list above (S1, S2, …, S6) are the most critical ones to be captured in TR 38.875 for UE antenna reduction?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1, S5 |
| FUTUREWEI | NONE |
| Ericsson | We do not see RAN1 specification impacts beyond potential associated coverage recovery and reduction of number of MIMO layers. |
| Sierra Wireless | S6 |
| Spreadtrum | S1, S2, S3, S4 |
| ZTE,Sanechips | S1,S3,S6 and other channel/signal related to coverage recovery |
| vivo | Same comment as above. |
| Samsung | S1, S3, S4, S5, S6, S7(Longer duration CORESET.) |
| OPPO | S1,S2,S3,S6 |
| Xiaomi | None.  S1-S5 should be discussed in the coverage recovery section  S6 should be discussed in the access control and UE capability indication section |
| CMCC | S1,S2,S4,S6 |
| Huawei, HiSilicon | S6 and peak data rate at this stage. For whether to capture the others, it depends on the output of coverage/SE evaluations. |
| Sequans | Potential coverage recovery solution(s) and S5, S6 |
| Lenovo, Motorola Mobility | S1, S6 |
| Intel | In general, coverage recovery and impact to max # of MIMO layers.  Beyond that, identification is not meaningful at this stage since we do not know if every individual channel needs to be “enhanced” irrespective of their final impact to overall performance against technical requirements for corresponding use-cases. |
| Nokia, NSB | This depends on the coverage recovery analysis. If coverage recovery is needed, we see S1, S2, S3, S4 as potential solutions |
| Qualcomm | S1-S6 are the candidate solutions that should be discussed for coverage recovery. |

### 7.2.6 Conclusions

Based on the analysis summarized in previous sections, several companies have explicitly indicated/proposed their preference on the number of UE Rx antennas as baseline support for RedCap. We summarize these preferences below. Superscript is used to indicate the notes.

**FR1:**

* **1 Rx:** [41, 15, 17, 21, 292, 3111]
* **2 Rx:** [2, 33, 18, 194, 274]
* **Both 1 Rx and 2 Rx:** [15, 56, 67, 85,8, 125, 165,9, 255]

**FR2:**

* **2 Rx:** [1, 6, 15, 18, 274]
* **Both 1 Rx and 2 Rx:** [56, 2910]

Notes:

* Note 1: 1 Rx for wearables. For devices types that are not very restricted by form factor, 2 Rx can be considered.
* Note 2: [29] has indicated that 2 Rx can be an optional feature in FR1.
* Note 3: FFS if 1Rx/1Tx should be recommended for some low frequency deployment for size considerations, or for scenarios where range is not an issue (e.g., wearables).
* Note 4: 2 Rx has higher priority than 1 Rx
* Note 5: 1 Rx in lower frequency bands in FR1, and 2 Rx in others.
* Note 6: Capability signaling shall be defined to indicate the number of Rx antennas
* Note 7: Does not recommend going from 4 Rx to 1 Rx in FR1. Reduced capability feature set 1 needs 2 Rx; Reduced capability feature set 2 can have either 2 Rx or 1 Rx (depending on band)
* Note 8: FFS: whether to support RedCap UE’s with 1 Rx in all FR1 bands
* Note 9: When operating in bands n7, n38, n41, n77, n78, n79, the number of Rx can be reduced from 4 to 2 or 1.
* Note 10: Consider two antenna configurations for UE capability, namely 1Rx/1Tx and 2Rx/1Tx
* Note 11: The support of 2 Rx is optional

Contribution [13] states that support for a 1 Rx should be the exception and should be an optional UE capability.

Contribution [28] indicates a preference for 2 MIMO layers (which requires 2 Rx) or 40 MHz in FR1

Contribution [32] mentions that the number of receive antenna for a RedCap UE need to be reported as a UE capability.

## 7.3 UE bandwidth reduction

### 7.3.1 Description of feature

For FR1, most of the contributions under AI 8.6.1 [1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31] consider 20 MHz maximum UE bandwidth in FR1. Contributions [5, 15, 16, 28] consider maximum UE bandwidth larger than 20 MHz as additional options in FR1.

For FR2, contributions [1, 3, 4, 5, 6, 8, 9, 11, 12, 13, 16, 17, 18, 19, 23, 24, 25, 26, 27, 28, 29, 31, 35] discuss 50 MHz and/or 100 MHz maximum UE bandwidth options in FR2. Contributions [4, 5, 8, 12, 16, 29] prefer maximum RedCap UE bandwidth 100 MHz, whereas contributions [1, 6, 11] prefer 50 MHz. Contribution [3] points out it might be desirable to preserve the economy of scale for the “normal” 200 MHz NR UE.”

Contribution [1, 3, 15, 22, 30] explicitly states that same bandwidth is considered for DL and UL. Contribution [1, 5, 20, 22, 30] also consider the same BW for RF and baseband. Contribution [22, 30] further states the same bandwidth for data and control channels. Contribution [8, 15] discusses whether asymmetric DL/UL bandwidth might be considered for certain use cases.

**Q 7.3.1-1: Can TR 38.875 focus on the scenario where the same maximum UE bandwidth applies to both DL and UL, both RF and baseband, and both data and control channels?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y | Including this main case is already agreed. No need to spend time on bandwidth proposals between 20 and 100 MHz for FR1. The target is “up to” and various combinations of modulation and MIMO layers can hit the peak data rate. Other proposals may have been considered in the “888” days but are not so promising for NR. Given the limited time unless most companies want to include we should work on completing other aspects of the study. |
| SONY | N | UL bandwidth could be larger than DL bandwidth as UL bandwidth is not a significant cost driver.  Having a wider RF bandwidth than baseband bandwidth could lead to better coexistence, so we would like this to be further studied.  There could be coexistence benefits for having a different control bandwidth to data bandwidth, so we would like to consider this. |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| DOCOMO | Y |  |
| InterDigital | Y. |  |
| Spreadtrum | Partially Yes | UE BW of data and control channel can be different. Data BW reduction can reduce cost further. |
| ZTE,Sanechips | Y |  |
| Sharp | Y |  |
| Panasonic | Y |  |
| vivo |  | In FR1 we agree that UE should support 20MHz, however some RedCap UEs may also support larger BW at least in DL to achieve a higher data rate, e.g. 40MHz in DL but 20MHz in UL can also be considered. |
| Samsung | Y |  |
| LG | Y | The focus should be set to the case where the max UE bandwidth applies to all. |
| OPPO | N | Share similar view as Sony. For some use case, such as video surveillance, UL bandwidth can be large than DL, this can help to reduce the UE’s cost. |
| Xiaomi | Y for FR and baselined, data and control  N for DL and UL | We are OK with same maximum bandwidth for RF and baseband, both data and control. But considering asymmetric DL/UL bandwidth was already supported in NR, we don’t see very strong motivation to preclude it. |
| CMCC | Y |  |
| Huawei, HiSilicon | Y | It is important to have a baseline assumption for BW as 20Mhz for FR1 for further study on other related aspects. |
| Sequans | Y | Primary focus should be on same maximum UE bandwidth. Going into asymmetric may lead to too detailed analysis (e.g. splitting cost of UL and DL in the processing) which may be counterproductive, depending on the accuracy of the cost breakdown (if agreed). |
| Lenovo, Motorola Mobility | Y |  |
| Intel | Y |  |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |
| FL |  | All responses except for one agree that the SI should only focus on the scenario where the same maximum UE bandwidth applies to both RF and baseband. One response indicates that wider RF bandwidth than baseband bandwidth could lead to better coexistence, so they would like this to be further studied.  All responses except for two ones agree that the SI should only focus on the scenario where the same maximum UE bandwidth applies to both data and control channels. One response indicates that there could be coexistence benefits for having a different control bandwidth to data bandwidth. Another response indicates that there is a cost benefit in reducing the data channels bandwidth further.  All responses except for three ones agree that the SI should only focus on the scenario where the same maximum UE bandwidth applies to both DL and UL. Three responses indicate that asymmetric DL and UL maximum bandwidth can also be considered.  Proposal:   * For RedCap UEs, the same maximum bandwidth applies to both RF and baseband. * For RedCap UEs, the same maximum bandwidth applies to both data and control channels. * For RedCap UEs, the same maximum bandwidth applies to both DL and UL. |

**Q 7.3.1-2: Should TR 38.875 include more bandwidth options in FR1 in addition to 20 MHz? If yes, what additional bandwidth options?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N |  |
| SONY | Y | We are basically OK with considering 20MHz bandwidth. However, as per the answer to Q7.3.1-1, we would like to consider wider RF bandwidths and / or control channels having a bandwidth of greater than 20MHz. |
| Ericsson | N |  |
| Sierra Wireless | N |  |
| DOCOMO | Y | Study the feasibility of 40 MHz BW to support high-end wearables (i.e. DL 150 Mbps) as an alternative. |
| InterDigital | N. |  |
| ZTE,Sanechips | Y | Redcap UE may support 40MHz after initial access |
| Sharp | N |  |
| Panasonic | Yes/No | The analysis can be sufficient for 20MHz but 40MHz operation candidate is not required to be excluded. |
| vivo | Y | As commented above, we consider 40MHz at least for DL for some Redcap devices |
| Samsung |  | Although we are open for other BW, e.g., 50MHz, we should focus on 20MHz and finish the analysis on 20MHz first. |
| LG | N | 20 MHz BW (with two MIMO layer) is sufficient to support the highest DL peak rate (i.e. 150Mpbs) of high-end wearables and every other data rate. From cost/complexity reduction point of view, any other bandwidths wider than the 20MHz are not desirable. |
| OPPO | Y | 1RX shall be supported for wearable, then large bandwidth may be needed for 150MBps data rate requirement. |
| Xiaomi | Y | Agree with DOCOMO’s view. For wearable devices, 20MHz+1Rx can’t reach the required peak data rate of 150Mbps. In our contrition [15], we provide detailed analysis on possible options to reach this peak data rate. One option is 20MHz+2Rx and another option is 40MHz+1Rx. For the option of 20MHz + 2Rx, this is not good for the wearable devices considering the tight requirement on the devices size. So, considering this aspect, we think more than 20MH should be supported at least for wearables. In that sense, we can compromise to QC’s proposal. |
| CMCC | Y |  |
| Huawei, HiSilicon | N |  |
| Sequans | N | It is OK with us to consider a higher than 20MHz bandwidth but important thing is to select one option and not work on multiple options to avoid overloading the workgroup. Maybe a good exercise could be to discuss in which bands RedCap devices may be deployed and check the available bandwidth. |
| Lenovo, Motorola Mobility | N |  |
| Intel | N for baseline | However, to satisfy the high-end wearables peak rates, larger BW or DL CA should be considered as optional features. |
| Nokia, NSB | N | We believe the requirements can be satisfied with 20MHz BW |
| MediaTek | N |  |
| Qualcomm | N for baseline UE feature of RedCap devices;  Y for optional UE feature of RedCap devices | Single carrier operation and 20 MHz should be supported as the baseline of BW capability in FR1.  However, for RedCap UE with device size limitation and 1T1R antenna configuration, larger than 20 MHz UE BW could be considered to meet the DL peak data rate requirements on the order of 150 Mbps. |
| FL |  | Approximately half of the responses indicate that it is enough to consider only 20 MHz.  One response is fine with considering the 20MHz bandwidth but indicates interests in considering wider RF bandwidths and/or control channels having a bandwidth of greater than 20MHz.  The other half of the responses indicate interests in considering a larger UE bandwidth. Almost all these responses further consider 40 MHz for achieving 150 Mbps in the DL. Two responses suggest that 20 MHz can be considered as a baseline UE feature of RedCap devices, while 40 MHz can be an optional UE feature of RedCap devices. One response indicates that they would be fine with such a compromise proposal.  Proposal:   * For RedCap UEs in FR1, the baseline UE bandwidth capability is 20 MHz, which can be assumed during the initial access procedure. Optional support of 40 MHz as an optional UE bandwidth capability can also be studied. |

**Q 7.3.1-3: Should TR 38.875 include more bandwidth options in FR2 in addition to 50 MHz and 100 MHz? If yes, what additional bandwidth options?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | Including 50MHz is a sufficient example for the long list of impacts and issues, no need to include another similar value. We had proposed last meeting to include a value just large enough (say in 70-80MHz) to avoid all of the issues with 50MHz, but 100MHz also avoids those issues.  As part of the TR analysis for 50 and 100 MHz we should say something like “a value of X MHz in FR2 will avoid these issues with 50MHz, but would require effort in RAN4 to define a new bandwidth.” (same comment we made in the May meeting GTW when accepting 50 and 100MHz) |
| SONY | Y | We are basically OK with considering 50MHz / 100MHz bandwidth. However, as per the answer to Q7.3.1-1 / Q7.3.1-2, we would like to consider wider RF bandwidths and / or control channels having a bandwidth of greater than 50MHz / 100MHz. |
| Ericsson | N |  |
| Sierra Wireless | N |  |
| DOCOMO | N |  |
| InterDigital | N. |  |
| Spreadtrum | No |  |
| ZTE,Sanechips | No | BTW, only support 100Mhz option |
| Sharp | N | As commended by FUTUREWEI, additional bandwidth options would require RAN4’s effort on defining a new one, considering current RAN4 specification only define the transmission bandwidth configuration as 50M, 100M, 200M, and 400M. |
| Panasonic | N |  |
| Samsung | N | No need. |
| LG | N | Considering supported channel bandwidths in FR2, the next bandwidth to consider will be 200MHz. Supporting larger than 100MHz will only bring a minor cost/complexity reduction from normal NR devices. We prefer not to consider the UE max bandwidth wider than 100MHz for redcap UEs for FR2. |
| OPPO | N |  |
| Xiaomi | N |  |
| CMCC | N |  |
| Huawei, HiSilicon | Partially Y | Our preference is 100Mhz only for FR2. A new channel bandwidth as e.g. 80Mhz as FUTUREWEI proposed can also be considered if RAN4 is willing to do such efforts. Overall, the main motivation is to minimize the specification impact. |
| Sequans | N |  |
| Lenovo, Motorola Mobility | N | No need to have more bandwidth options, but UE could be configured with smaller size BWP. |
| Intel | N | In fact, we suggest to focus on 100 MHz case (similar views as Futurewei here). Note that operation with smaller active BWPs in connected mode is always possible by NW configuration and not precluded. |
| Nokia, NSB | N | We believe the requirements can be satisfied with 50MHz / 100MHz BW |
| MediaTek | N |  |
| Qualcomm | Y | We can consider smaller bandwidths for active BWP (e.g., 20 MHz). The UE may be able to switch to smaller BW after initial across to save power. For example, data rates for industrial wireless sensors may not need the full 100MHz BW used for initial access and can choose to limit its BW to conserve power. |
| FL |  | Most responses indicate the 50 MHz and 100 MHz options are enough. Two responses suggest focussing only on the 100 MHz option.  One response indicates that they are fine with considering the 50 MHz and 100 MHz options but indicates interests in considering wider RF bandwidths and/or control channels having a bandwidth of greater than 50MHz / 100MHz.  Two responses indicate an interest in a bandwidth smaller than 100 MHz but larger than 50 MHz to avoid some of the issues with 50MHz. One of these responses proposes a note to capture this aspect: “A value of X MHz in FR2 will avoid these issues with 50MHz but would require effort in RAN4 to define a new bandwidth” (there is a similar suggestion in response to Q7.3.4-3 which is captured as a new coexistence aspect).  One response indicates that there is a power-saving benefit in allowing the UE to switch to a smaller BW after initial access.  Proposal:   * The SI only focuses on 50 MHz and 100 MHz options in FR2.   + Note: this does not preclude the possibility of UE switching to a smaller bandwidth after initial access. |

### 7.3.2 Analysis of UE complexity reduction

Contributions [1, 4, 7, 8, 16, 17, 18, 22, 23, 30] specifically indicate that UE bandwidth reduction has impact on the functional blocks listed below.

* Power amplifier: [1, 8, 18]
* ADC/DAC [1, 7, 8, 16, 17, 18]
* Frontend buffering [8]
* FFT/IFFT [1, 4, 7, 8, 16, 22, 23, 30]
* Post-FFT processing or data buffering [1, 4, 7, 16, 22, 30]
* Channel estimation [7, 8, 23]
* HARQ or decoder buffer [1, 4, 8, 16, 22, 23, 30]
* Decoder [1, 8, 16, 22, 23, 30]
* UL processing block, although some contributions also indicate the benefit is minor [1, 7, 8, 22, 30]

Contributions [1, 3, 5, 6, 7, 17, 20, 22, 30] provide quantitative analysis and contributions [3, 5, 12] provide qualitative analysis on UE cost saving.

The estimates in cost reduction achieved by reducing the maximum UE bandwidth from 100 MHz to 20 MHz in FR1 are:

* Contribution [3]: 20%-30%
* Contribution [17]: 27.6% (FDD), 23.8% (TDD)
* Contribution [20]: 34.5%
* Contribution [1]: 15%-39%
* Contribution [6]: 38%
* Contribution [22, 30]: 67% in baseband cost; with 40:60 RF:baseband cost ratio, this translate to 40.2% cost reduction
* Contribution [7]: 51.4% for baseband processing; with a 40:60 RF:baseband cost ratio, this translate to 29% cost reduction
* Contribution [5]: significant

Based on these estimates, the cost saving from reducing the UE bandwidth from 100 MHz to 20 MHz is in the range of 15%-51.4% The middle of this range is 33.2%

The estimates in cost reduction achieved by reducing the maximum UE bandwidth from 200 MHz to 100 MHz in FR2 are:

* Contribution [3]: Less benefit compared to that achievable in FR1
* Contribution [17]: 10.5%
* Contribution [1]: <10%
* Contribution [6]: 23%
* Contribution [5]: significant

Based on these estimates, the cost saving from reducing the UE bandwidth from 200 MHz to 100 MHz is no greater than 23%

The estimates in cost reduction achieved by reducing the maximum UE bandwidth from 200 MHz to 50 MHz in FR2 are:

* Contribution [17]: 16.5%
* Contribution [1]: 15%
* Contribution [6]: 32%
* Contribution [3]: Less benefit compared to that achievable in FR1
* Contribution [12]: Complexity reduction benefits from 50 MHz compared to 100 MHz in FR2 may be rather limited

Based on these estimates, the cost saving from reducing the UE bandwidth from 200 MHz to 50 MHz is in the range of 15%-32% The middle of this range is 23.5%

### 7.3.3 Analysis of performance impacts

Contributions [1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15, 16, 17, 18, 20, 21, 27, 28, 29] analyze the performance impact in FR1 due to bandwidth reduction from 100 MHz to 20 MHz.

**Data rate:**

* P1: There is peak data rate reduction due to bandwidth reduction [7, 18]
* P2: 20 MHz bandwidth can either achieve or sufficiently close to achieve data rate requirements for all targeted use cases [2, 3, 6, 8, 21, 27]
* P3: 64QAM without MIMO achieves greater than 80 Mbps in DL [5, 13, 29, 13]
* P4: 64QAM without MIMO achieves greater than 50 Mbps in UL [13, 29]
* P5: 16QAM without MIMO achieves greater than 40 Mbps in UL [13, 29]
* P6: A UE bandwidth of 20MHz without MIMO cannot achieve DL peak bit rate of 150Mbps. To achieve 150 Mbps in DL, either MIMO, CA, or larger bandwidth than 20 MHz is needed. [3, 5, 9, 12, 15, 16, 27, 28, 29]
* P7: A DL peak rate of 150Mbps is not possible with TDD, 20MHz UE BW, and 64 QAM [13]

**Latency:**

* P8: The latency can be increased if the large messages need to be segmented into multiple transport blocks and sent over multiple slots. But, 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. [7]

**Reliability:**

* P9: Reliability should not be impacted as it is envisaged that BLER targets can still be achieved at a reduced bandwidth. [7]

**Power consumption:**

* P10: Power saving benefit: [4, 5, 6, 15, 20,]

**Spectral Efficiency:**

* P11: Minimal spectral efficiency degradation [6, 7, 17]
* P12: CORESET#0 capacity before RRC connection setup and impact as such on spectral efficiency [17, 20]

**PDCCH blocking probability**

* P13: PDCCH blocking probability may increase [20]

**Coverage:**

* P14: PDSCH performance degradation (based on the same data rate target) [9]
* P15: Minor or no coverage loss [1, 6, 7, 17]

Some of performance impact identified above can be expected also in FR2

Contributions [1, 4, 5, 6, 9, 12, 16, 18, 19, 23, 26, 27, 28, 29] identify the performance impact due to UE bandwidth reduction in FR2.

Impacts common to 50 MHz and 100 MHz

* P16: In FR2, both maximum UE bandwidth 50 MHz and 100 MHz can meet the peak data rate requirement. [5, 6]
* P17: SSB/CORESET acquisition time can be impacted if the UE bandwidth is reduced [28]
* P18: Misalignment between Redcap UE’s receiving bandwidth and PDSCH scheduling bandwidth [16]
* P19: Severely limiting the gNB scheduler in managing load on the initial DL BWP [12]

Impacts identified specific to 50 MHz UE bandwidth

* P20: UE may not be able to receive AL 8 or 16 for certain CORESET#0 configurations [26, 29]
* P21: PDCCH blocking probability [4, 5, 9, 16, 18, 27, 28, 29]
* P22: Reduce the number of users that can be supported by almost 50% if the maximum UE BW is reduced from 100 MHz to 50 MHz [29]
* P23: Lower mean SINR compared to the 100 MHz case [29]
* P24 Regarding PBCH performance degradation, contributions [1, 6, 23] analyze the loss.
  + very modest [1]
  + < 1 dB [23]
  + 0.6 dB [6]
* P25: Regarding PDCCH performance degradation when CORESET#0 is configured to 69.12 MHz, contributions [1, 6] analyze the loss.
  + 1.5-1.7 dB [1]
  + Not expected to have a significant impact to system performance [6]

**Q 7.3.3-1: Does the list (P1, P2, …, P15) above capture the most important performance impacts that need to be considered for bandwidth reduction in FR1? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y | Was the intent to stop at P15? |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | Y |  |
| Panasonic | Y |  |
| vivo |  | FR1  For data rate: we think P1/2/6/7 are important ones.  For latency: fine with P8  For reliability: fine with P9  For power consumption: fine with P10  For spectrum efficiency: fine with P11. P12 is conditional, the issue may happen if the RedCap UEs cannot be offloaded to other BWPs  For PDCCH blocking: P13 is conditional, the block may increase if the RedCap UEs cannot be offloaded to other BWPs.  For coverage: P14 and P15 seems contradictive to each other? |
| Samsung |  | To align with other feature on whether to add coverage analysis  Some observations needs to be further discussed and revisited. |
| OPPO | Yes |  |
| Xiaomi | Y |  |
| CMCC | Y | One little comment about P21, we don't analyse the PDCCH blocking probability in our contribution, and the contribution index [19] can be removed as the following  • P21: PDCCH blocking probability [4, 5, 9, 16, 18, 27, 28, 29] |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | Y |  |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.3.3-2: Which of the identified performance impacts or aspects in the list above (P1, P2, …, P15) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR1?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1, P2 |
| FUTUREWEI | Should capture:  P1, P2, P4, P11/14/15 should probably be combined into a small performance loss statement (no mention of COVERAGE LOSS)  No strong feeling:  P8,9  Should not capture:  P3, 5 as related to another technique which, if included, should be analysed on top of bandwidth reduction  P6,7: The requirements are “up to”, saying “cannot achieve” or “is not possible” may give the impression that it is a hard requirement. CA and BW larger than 20MHz should not be mentioned. p7 belongs in modulation restriction if that technique is included.  P12 seems not a spectral efficiency argument but more a coexistence or system impact  P13 no need to discuss for FR1 |
| Ericsson | P1, P2, P3, P6, P8, P9, P10, P11, P15  Regarding P12 and P13, we agree these performance aspects are important. But further studies are needed. |
| Sierra Wireless | P1-P7, P9, P10 |
| Spreadtrum | P1, P10, P13, P14 |
| ZTE,Sanechips | P6, P10, P11 |
| Panasonic | P1, P6, P7 |
| vivo | For FR1: P1/2/6/7/8/9/10 |
| Samsung | P2, P10, P11, P12, P13, P15 |
| OPPO | P2/P10/P11/P15 |
| Xiaomi | P3,P4,P5,P6,P7,P11,P15 |
| CMCC | P1-P7,P10,P11,P12,P13,P17 |
| Huawei, HiSilicon | P1, P2, P4, P6, P7, P8, P9, P11, P15 are critical.  P3 is unclear why 80Mbps is chosen as a target and why MIMO layers is not preferred in such observation. P5 has a similar issue.  P10 is not critically needed as BW reduction is not aimed for achieving power saving benefit. P13/P14 also seems to be looking at a non-targeted aspects but can be further studied.  P12 needs further study, as our view that 20MHz BW is the same as legacy so for initial access it does not affect the SE. |
| Sequans | P1-P6, P10-P13, P15 |
| Lenovo, Motorola Mobility | P1, P2, P8, P9, P10, P11, P12, P13, P15 |
| Intel | P1, P2, P6, P9, P10. |
| Nokia, NSB | P1, P2, P9, P10, P11, P15 |
| MediaTek | P1, P2 (may be combined with P6 P7), P4, P8, P9, P11, P15  P3, P5 could be mentioned in the section where restriction on maximum modulation order is discussed. |
| Qualcomm | P1, P2, P3, P4, P5, P6, P8, P9, P10, P11, P15 |

**Q 7.3.3-3: Does the list (P1, P2, …, P25) above capture the most important performance impacts that need to be considered for bandwidth reduction in FR2? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y |  |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | Y |  |
| Panasonic | Y |  |
| vivo |  | FR2  For impacts common to 50 MHz and 100 MHz: P16 is fine. If UE can support 100MHz, not sure if P17/18 are still valid. P19 is conditional if the RedCap cannot be offloaded to other BWPs  For impacts identified specific to 50 MHz UE bandwidth: P20/24/25 are fine |
| Samsung |  | To align with other feature on whether to add coverage analysis  Some observations needs to be further discussed and revisited. |
| OPPO | Yes |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | N | Propose adding a P26 (specific to 50 MHz): “Precludes FDM-based multiplexing patterns between SSB and CORESET #0.”  For FR2, we think this is a serious scheduling constraint to scheduling that heavily relies on analogue beamforming. |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y | Please add [29] to P20 |

**Q 7.3.3-4: Which of the identified performance impacts or aspects in the list above (P1, P2, …, P25) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1, P2 |
| FUTUREWEI | Should capture: P16,P17 (where more impact is expected for 50MHz), P20-22, P24-25 (need to be rewritten to emphasize that there is a degradation, then the dB range (so far).  No strong feeling: P23  Should not capture:  P18 issue not clear  P19 more a coexistence issue |
| Ericsson | P1, P9, P10, P11, P15, P16, P17, P23, P24, P25  Regarding P12, P13, P19, and P21, we agree these performance aspects are important. But further studies are needed. |
| Sierra Wireless | P17 |
| ZTE,Sanechips | P20,P22,P23 |
| Panasonic | P17, P24, P25 |
| vivo | For FR2: P16/24/25 |
| Samsung | P11, P12, P13, for both FR1 and FR2  P16, P20, P21 for FR 2 |
| OPPO | P18  Since PDSCH for SIBx and other common messages are scheduled by the gNB with DCI, the PDSCH may not occupy the whole initial DL BWP. Redcap UE’s receiving bandwidth may not fully overlap with the PDSCH scheduling bandwidth, as shown in Figure 1. In this case, the PDSCH decoding performance will deteriorate. Therefore, method to avoid such mis-alignment between Redcap UE’s receiving bandwidth and PDSCH scheduling bandwidth shall be further studied.    Figure 1 Mis-alignment between Redcap UE’s receiving bandwidth and PDSCH scheduling bandwidth |
| CMCC | P20,P21,P24,P25 |
| Huawei, HiSilicon | P1, P2, P4, P6, P7, P8, P9, P11, P15, P16, P17, P20, P21, P22, P23, P24, P25 |
| Sequans | P16, P17, P20, P21, P25 |
| Lenovo, Motorola Mobility | P1, P8, P9, P10, P11, P12, P13, P15, P16, P17, P20, P21 |
| Intel | P9, P10, P16, P19, P20, P22, P26 (proposed to be added in response to Q 7.3.3-1). |
| Nokia, NSB | P16, P20, P21, P24, P25 |
| MediaTek | P1, P2 (may be combined with P6 P7), P4, P8, P9, P11, P15, P16, P17  P20, P21, P23  Agree with qualitatively stating the degradation in P22. |
| Qualcomm | P1, P8, P13, P14, P16, P17, P20, P21, P24, P25 |

### 7.3.4 Analysis of coexistence with legacy UEs

Contributions [1, 3, 4, 5, 7, 11, 20] analyze the coexistence issues with legacy UEs. The findings are:

* C1: Small overall impact [1, 20]
* C2: Fully reusing the legacy procedure for RedCap UEs will potentially impact the performance of legacy UEs during initial access and increase the load of the initial BWP [4, 11]
* C3: Longer processing time for PRS is needed [7]
* C4: Paging capacity may be a concern [5]
* C5: Resource fragmentation and reduced peak data rates available for non-RedCap UEs [3]
* C6: Coexistence with URLLC UEs [11]

**Q 7.3.4-1: Does the list above (C1, C2, …, C6) capture the most important coexistence impacts and findings that need to be considered for bandwidth reduction in FR1? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y |  |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | Y |  |
| Panasonic | Y |  |
| vivo |  | We think C2 and C4 are important aspects that should be addressed for high load scenario. If the cell load is not a concern, i.e. no massive RedCap UEs, the overall impact should be small, i.e. C1. |
| Samsung |  | C3: PRS is not a part of the study focus.  Some observations need to be further discussed, e.g, C5. |
| OPPO | Y |  |
| Xiaomi | Y |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | Y |  |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.3.4-2: Which of the identified coexistence impacts in the list above (C1, C2, …, C6) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR1?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | C1, C2 |
| FUTUREWEI | Should capture:  C5. We had a similar statement in 888.  No strong feeling:  Should not capture:  C1: This is not compatible with the other statements. Better to list the impacts. Also, not applicable to FR2.  C2: This seems more an issue for FR2. |
| Ericsson | C1, C3.  Regarding C2, C4, C5, and C6, further discussions are needed. |
| Sierra Wireless | C5 |
| Spreadtrum | C1 |
| ZTE,Sanechips | C1 |
| Panasonic | C1 |
| vivo | For high load scenario, C2, C4, otherwise C1. |
| Samsung | C2, C4, |
| OPPO | C1,C2,C4 |
| Xiaomi | C1,C2 |
| CMCC | C2, C4 |
| Huawei, HiSilicon | C2, C5 |
| Sequans | At least C1, C2, C5 |
| Lenovo, Motorola Mobility | C2 |
| Intel | C1 |
| Nokia, NSB | C1 |
| MediaTek | C1,C2, C5 |
| Qualcomm | C1, C2 |

Some of the coexistence impacts identified for FR1 above might be relevant for FR2.

Concerning 50 MHz UE bandwidth in FR2, contributions [3, 5, 17, 29] highlight the following issues.

* C7: Restrictions on SSB/CORESET#0 configurations or Type0-PDCCH monitoring [3, 17, 5]
* C8: PDCCH blocking probability increases [29]
* C9: Half capacity compared to 100 MHz with a TDM scheduler [29]
* C10: Reduced SIR compared to 100 MHz [29]

**Q 7.3.4-3: Does the list above (C1, C2, …, C10) capture the most important coexistence impacts and findings that need to be considered for bandwidth reduction in FR2? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | As above, should have a statement like “a value of X MHz in FR2 will avoid these issues with 50MHz, but would require effort in RAN4 to define a new bandwidth.” |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | N | Seems not a complete lists. PDCCH performance …UE retuning complexity |
| Panasonic | Y |  |
| vivo |  | We think C7 is more important. |
| Samsung | Yes | Some observations need to be further discussed |
| OPPO | N | C11, Misalignment between Redcap UE’s receiving bandwidth and PDSCH scheduling bandwidth shall also be considered |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | N | Propose to add a C11: “Higher system information acquisition delay due to infeasibility of frequency division multiplexing between SSB and CORESET 0 for 50 MHz”. FDM-based SSB-CORESET0 multiplexing patterns are not possible even for 120 kHz SCS (both SSB and control/data) for 50 MHz max BW. |
| Nokia, NSB | Y |  |
| MediaTek | N |  |
| Qualcomm | Y |  |

**Q 7.3.4-4: Which of the identified coexistence impacts in the list above (C1, C2, …, C10) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | C1, C2 |
| FUTUREWEI | Should capture: C7  C2 should be rewritten: For 50MHz, two initial access procedures will have to coexist: one for ‘regular’ UEs, one for RedCap UEs  No strong feeling:C8,C9,C10  Should not capture:  C1 (for at least 50MHz) |
| Ericsson | C3, C7.  Regarding C7: we agree this aspect should be captured in the TR. However, our view is that all the currently defined SSB/CORESET#0 configurations can be reused. One restriction we see is that the UE needs to detect SSB and SIB1 in a sequential manner for certain SSB/CORESET#0 configurations.  All the other coexistence impacts need to be discussed further. |
| Sierra Wireless | C7 |
| ZTE,Sanechips | If 100MHz are adopted then there is no concern. For 50MHz most in the list are all critical issues need to be resolved |
| Panasonic | C7 |
| vivo | C1 |
| Samsung | C7 C8 |
| OPPO | For 50MHz case, Misalignment between Redcap UE’s receiving bandwidth and PDSCH scheduling bandwidth shall also be considered |
| CMCC | C7,C8 |
| Huawei, HiSilicon | C2, C5, C7, C8, C9, C10 |
| Sequans | At least C7 |
| Lenovo, Motorola Mobility | C2, C7, C8 |
| Intel | C2, C11 (proposed to be added as in response to **Q 7.3.4-3**) |
| Nokia, NSB | C7 |
| MediaTek | C5, C7, C8 |
| Qualcomm | C4, C7, C8, C9 |

### 7.3.5 Analysis of specification impacts

Contributions [1, 3, 5, 6, 7, 15, 16, 17, 19, 21, 24, 25, 28] identify problem mitigating or performance enhancing solutions which have specification impacts in FR1.

* S1: Dedicated iBWP for RedCap [15, 16, 19]
* S2: Extending the CORESET duration in time domain to enhance the CORESET capacity [15]
* S3: UE behavior (not expecting resource allocations exceeding the number of PRBs corresponding to the maximum UE bandwidth [3]
* S4: FDMed RACH Occasions: [1, 5, 21, 28,]
* S5: Multiple initial BWPs [17, 19]
* S6: CSI report enhancement [17]
* S7: CORESET#0 enhancement [17]
* S8: Capability signaling defining reduced bandwidth or UE type identification [5, 7]
* S9: Minor performance impacts to be reflected in RAN4 specifications [7]
* S10: DCI optimization [5]
* S11: Dedicated PO configuration [5]
* S12: PUCCH frequency hopping during initial access [1]
* S13: Msg3 frequency hopping [5]
* S14: define RedCap narrowband [24]

Contributions [1, 6, 25] conclude that overall specification impact is minimal.

**Q 7.3.5-1: Does the list above (S1, S2, …, S14) capture the most important specifications impacts that need to be considered for bandwidth reduction in FR1? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | Most of these should not be listed here. The SID is clear that L1 changes should be minimized. Mitigating performance degradation is a different section of the TR and should not be discussed here |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | Y |  |
| Panasonic | Y |  |
| vivo |  | We think S1/4/5/8/ are more important ones.  In addition, as in [4] we proposed to consider multiple BWPs in frequency domain for RedCap UEs, in this case, it is preferable that UE can assume SSB transmission in its active BWP, which means network needs to transmit multiple SSBs in frequency domain. |
| Samsung | Y | Some observations need to be further discussed.  We suggest to identify the issue first and then categorize the solutions for the issues. Some solution can be combined. |
| OPPO | Y |  |
| Xiaomi | Y |  |
| CMCC | Y | In our contribution [19], we propose different initial BWPs can be used to serve the RedCap UE to realize traffic offload, so the contribution index [19] are added to S1 and S5. |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel |  | Prefer not to aim for a “laundry list” here if the intention is to capture in TR. At this stage, should be sufficient to level-up to descriptions like “solutions to harvest sufficient frequency diversity”, “solutions for DL coverage”, etc.  On the other hand, if the intention is to consider this as a “down-selected list”, then we think such an attempt is too pre-mature at this stage given lack of proper analyses of exactly what would need to be done, and which schemes would actually have a net positive benefit. Thus, it would be good to first get some clarification on how to interpret the question/proposal for our future work. |
| Nokia, NSB | Y |  |
| Qualcomm | Y |  |

**Q 7.3.5-2: Which of the identified specification impacts in the list above (S1, S2, …, S14) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR1?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1, S2 |
| FUTUREWEI | Should capture: S3, S9  No strong feeling:  Should not capture:  All others |
| Ericsson | S4, S8, S12 |
| Sierra Wireless | S8, S9 |
| ZTE,Sanechips | Most of the item in the list are enhancement that should be put in low priority. S8 may be considered since it has to be implemented anyway. |
| vivo | S1/4/5/8 and the “multiple SSB transmission in frequency domain” as mentioned above. |
| Samsung | We suggest to identify the issue first and then category the solutions for the issues. Some solution can be combined.  S1, S2, S3, S4, S5, S6, S7, S8, S12, S13, S14 |
| OPPO | S4/5/11 |
| Xiaomi | S1,S2,S3,S4 |
| CMCC | S1, S5,S7,S8  Regarding S1 and S5, we think network should have the capability to decide whether to offload RedCap UE to separate initial BWP(s). |
| Huawei, HiSilicon | S8/S9 may be direct specification impact that can be considered;  the others are related to coverage/capability study thus can be further considered later. |
| Sequans | S4, S5, S8 |
| Lenovo, Motorola Mobility | S2, S3, S8 |
| Intel | Too early to prioritize as “most critical” since we do not exactly know the challenges to overall operation or the net impact from each “enhancement”. At present, only S3, S8, S9 can be anticipated. |
| Nokia, NSB | S4, S8, S12 |
| Qualcomm | S3, S8, S10 |

Some of the identified specification impacts listed above might be relevant to FR2 as well.

Specification impacts required for supporting 50 MHz maximum UE bandwidth in FR2 are identified in contributions [3, 4, 5, 11, 12, 16, 17, 19, 24, 25, 26, 28, 29, 31, 35].

* S15: Initial access due to {SSB, CORESET#0} together or PBCH or CORESET#0 alone spanning a bandwidth larger than 50 MHz [3, 4, 5, 6, 11, 12, 17, 19, 24, 25, 26, 27, 28, 29, 31]
* S16: Limiting the supported SCS combinations for {SSB, CORESET#0} [19]
* S17: Dedicated initial BWP [26]
* S18: RMSI acquisition or initial access procedure for RedCap [3, 11, 25]
* S19: Mechanism for dealing with misalignment between UE receiving bandwidth and PDSCH scheduling bandwidth [16, 25]
* S20: Cell barring [25]
* S21: The minimum guardband of SCS 240 kHz SSB is not defined for 50 MHz bandwidth in the RAN4 spec [35]

Contribution [25] mentions that mechanism for allowing omitting reception of channel/signal outside of UE supportable maximum bandwidth is also needed for supporting maximum 100 MHz UE bandwidth.

Contribution [28] mentions that a special SSB/CORESET#0 configuration might also be considered for supporting 100 MHz UE bandwidth.

Contribution [6] states that specification impact for supporting 50 MHz or 100 MHz maximum UE bandwidth is small.

**Q 7.3.5-3: Does the list above (S1, S2, …, S21) capture the most important specifications impacts that need to be considered for bandwidth reduction in FR2? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | Many of these should not be listed here. The SID is clear that L1 changes should be minimized. Mitigating performance degradation is a different section of the TR and should not be discussed here. |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Yes |  |
| ZTE,Sanechips | Y |  |
| Panasonic | Y |  |
| vivo |  | We think S15/16/17 are important ones |
| Samsung | Y | Some observations need to be further discussed. |
| OPPO | Y |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel |  | Prefer not to aim for a “laundry list” here if the intention is to capture in TR. At this stage, should be sufficient to level-up to descriptions like “solutions to harvest sufficient frequency diversity”, “solutions for DL coverage”, etc.  On the other hand, if the intention is to consider this as a “down-selected list”, then we think such an attempt is too pre-mature at this stage given lack of proper analyses of exactly what would need to be done, and which schemes would actually have a net positive benefit. Thus, it would be good to first get some clarification on how to interpret the question/proposal for our future work. |
| Nokia, NSB | Y |  |
| Qualcomm | Y | - BWP hopping: to reduce the NB interference effects and achieving frequency diversity gains  - Optimizing measurements and procedures (e.g., paging, RLM/RRM/BM/BFD/BFR) and reducing the need for additional resource overhead or increased UE BW switching  - Reusing resources between eMBB and RedCap  - Recovering the tracking quality loss due to smaller BW operation  - L1 measurement report optimizations |

**Q 7.3.5-4: Which of the identified specification impacts in the list above (S1, S2, …, S21) are the most critical ones to be captured in TR 38.875 for bandwidth reduction in FR2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1, S2 |
| FUTUREWEI | Should capture: S3, S9  S15+S19 may be OK if clarified or rewritten  Should not capture:  All others  Restrictions on supported SCS S16/21 is a big restriction for NR systems, we should be extremely hesitant to go down this path especially for a small potential complexity gain that is not significant compared to economies of scale. |
| Ericsson | S4, S8, S12, S19, S21 |
| Sierra Wireless | S8, S9, S15 |
| ZTE,Sanechips | S15, S9 |
| Panasonic | S15 |
| vivo | S15/16/17 |
| Samsung | S15, S17 |
| OPPO | S18/19 |
| CMCC | S1, S5,S7,S8,S15,S16,S17 |
| Huawei, HiSilicon | S8/S9, S15, S16 |
| Sequans | At least S15 |
| Lenovo, Motorola Mobility | S15, S17, S18 |
| Intel | Too early to prioritize as “most critical” since we do not exactly know the challenges to overall operation or the net impact from each “enhancement”. At present, only S3, S8, S15, S16, S17 can be anticipated. |
| Nokia, NSB | S4, S8, S12, S15 |
| Qualcomm | S14, S15, S16, others (please see QC’s comments for Q 7.3.5-3) |

## 7.4 Half-duplex FDD operation

### 7.4.1 Description of feature

With half-duplex FDD (HD-FDD) operation, the device does not need to simultaneously transmit and receive at the same time. This allows the device to use a switch in place of one or more duplexers, typically one per frequency band. As of NR Rel-16, since the FDD bands are all in FR1, i.e. all FR2 bands use TDD, HD-FDD is only pertinent to FR1.

In LTE, two types of HD-FDD operation are specified:

* **Type A:** a DL-to-UL guard period is created by the UE by not receiving the last part of a DL subframe immediately preceding an UL subframe from the same UE, and no UL-to-DL guard period is defined (but can potentially be created by the eNB implementation by proper TA adjustment).
* **Type B:** a DL-to-UL guard period is created by not requiring the UE to receive a DL subframe immediately preceding an UL subframe from the same UE, and an UL-to-DL guard period is created by not requiring the UE to receive a DL subframe immediately following an UL subframe from the same UE.

HD-FDD operation type A is defined for normal LTE, whereas type B is defined for LTE-MTC and NB-IoT. The intention of type B is to facilitate UE implementations with a single oscillator for Tx and Rx frequency generation by introducing significantly longer DL-to-UL and UL-to-DL guard periods.

Contributions [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 20, 21, 22, 23, 25, 26, 27, 29, 30, 31] discuss HD-FDD for UE complexity reduction. Contributions [5, 8, 13, 17, 21, 26, 29] explicitly indicate supportive of introducing or considering HD-FD for RedCap. Contribution [21] suggests to study both Type A and Type B, whereas contributions [1, 4, 6, 8, 13] either suggest no need to study type B further or indicate a preference of type A. Contributions [2, 15] indicate not supportive of introducing HD-FDD or mandating the support of HD-FDD for RedCap, although contribution [15] indicates that HD-FDD can be an optional feature for RedCap.

**Q 7.4.1-1: Regarding HD-FDD, which of the below way-forwards shall be adopted?**

* **A: Both Type A and Type B are studied**
* **B: Only study Type A**
* **C: No need to study HD-FDD further, neither Type A nor Type B**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | We already agreed to study, with type A as a priority. Do you mean whether to include in the TR or not?  B or C are OK. A increases the priority of Type B so not OK.  Overall the antenna reduction and BW reduction are the most important, and this technique is not applicable to TDD. So we can accept not studying further if the group wants to go that way. We are also OK to spend a little time to include the benefits and impacts in the TR, which could (perhaps) help avoid spending time in the WI or in a future release.  Note: there is an outlier 19%, which would be misleading if in the TR. If we state that “most companies see ~5-10%” then should be OK. |
| SONY | A: At this stage, we should study both Type A and Type B, but we think that the eventual conclusion is likely to be that Type A is supported. |
| Ericsson | B |
| Sierra Wireless | B. The study should include HD-FDD. |
| DOCOMO | Support Option B. As the complexity reduction benefit by HD-FDD is not so significant, we think studying Type A is sufficient considering the performance impact of Type B. |
| InterDigital | A: Both type A and type B. |
| Spreadtrum | A |
| ZTE,Sanechips | B |
| Sharp | B.  HD-FDD type B would mainly require RAN4’s effort on specifying the guard time. The cost reduction by reducing one oscillator is marginal for whole cost of UE. |
| Panasonic | B. Because of the time limitation, we are ok to study only type A. |
| vivo | B or C |
| Samsung | A  We suggest to capture analysis and observations for both Type A and Type B in the TR. We can further discuss on the recommendation in the end of SI. |
| LG | A. Agree with Sony. Furthermore, we don’t expect the work load to become much larger when we work on both of them compared to working Type A only. |
| OPPO | B or C |
| Xiaomi | A or B. We are supportive to study HD-FDD further. From our understanding, the benefit of reducing oscillator on cost reduction may be marginal, and thus type A should be prioritized over type B. But we are open on whether to study Type B further. |
| CMCC | B |
| Huawei, HiSilicon | C, or HD-FDD is an optional feature, similar to [15] (in case the spec impact can be minimized). HF-FDD is not widely implemented even in LTE based on our observation. Given the negative performance impact it would bring to the network and the potential specification impact identified above, we suggest it is not further pursued in Rel-17 RedCap. |
| Sequans | C: The benefit does not seem to be significant enough for the effort needed, and we should also consider that most of NR bands are TDD; in FDD bands, LTE will be operated for long. We are also fine with the suggestion from Futurewei to spend little time to include observations on benefits and impacts in the TR, so as to help saving time in a future release |
| Lenovo, Motorola Mobility | B |
| Intel | Option B (focus on Type A only). |
| Nokia, NSB | B: Only study Type A |
| MediaTek | B (because Type A operation allows sparing the duplexer per each band.) |
| Qualcomm | B |
| FL | A vast majority of the responses prefers Option B, i.e. to only study Type A. There are also a few responses who want to study both Type A and B, and a few responses who do not want to study HD-FDD at all. All in all, there does not appear to be a clear consensus to revise the RAN1#101e agreement.  Recommendation: Continue in line with the RAN1#101e agreement, i.e.:   * Study HD-FDD operation Type A and Type B (as defined in LTE) in RAN1, where study of Type A is prioritized. |

### 7.4.2 Analysis of UE complexity reduction

Contributions [1, 2, 3, 4, 5, 6, 8, 10, 13, 15, 17, 20, 21, 22, 25, 26, 30] analyze the UE complexity or cost reduction benefits achieved by HD-FDD quantitatively. The findings are:

* 4%-19% [1]
* 4.5% and 8.1% for Type A/B respectively [17]
* 4%-8% [5, 25]
* 5-10% [3]
* 6% [6]
* 8% [20]
* <10% [2]
* 50% saving on RF part [22, 30]

Thus, the range of UE cost saving is from 4% to 19%.

### 7.4.3 Analysis of performance impacts

Contributions [1, 2, 3, 5, 6, 7, 8, 13, 15, 17, 20, 21, 22, 25, 27, 29, 30] analyze the performance impact if HD-FDD is introduced for RedCap UEs. The findings are listed below. Some of the items were identified to be studied further.

* P1: no coverage loss [1, 3, 6, 17, 20, 21, 22, 25, 29, 30]
* P2: lower power consumption, lower maximum power peaks, lower power state, or lower insertion loss [3, 5, 6, 7, 8, 13, 20, 21, 29]
* P3: lower noise figure [1, 6, 7, 17, 29]
* P4: lower (peak) data rates or throughput [2, 3, 5, 6, 7, 15, 27, 29]
* P5: increase PUSCH/PDSCH SINR requirements [2, 21]
* P6: larger number of HARQ processes may be required, which increases the UE buffer occupation and processing complexity [2]
* P7: no impact on spectral efficiency or capacity [3, 6, 7, 17, 20]
* P8: coverage impact for delay sensitive services [27]
* P9: negative impact on latency [2, 7, 15, 27, 29]
* P10: more complicated scheduling at the gNB, more scheduling constraints, or significant impact on network [2, 3, 21, 27]
* P11: Scheduling effectiveness is not jeopardized by supporting Type-A half-duplex UE’s in paired spectrum [8]
* P12: Contributions [1, 5] analyze latency and conclude that an HD-FDD device in RRC\_CON14TED can meet the 5-10 ms latency requirement for safety related sensors.

These performance impacts can be classified as follows:

* Peak data rate: P4
* Latency: P8, P9, P12
* Power consumption: P2, P3,
* Spectral efficiency: P3, P5, P7
* PDCCH blocking probability
* Coverage: P3, P5, P8
* UE buffer and processing complexity: P6
* Scheduling and network: P10, P11

**Q 7.4.3-1: Does the list (P1, P2, …, P12) above capture the most important performance impacts that need to be considered for HD-FDD? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y |  |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | Y |  |
| Samsung | Y | Some observations need to be further discussed. |
| OPPO | Y |  |
| Xiaomi | Yes | We agree on FL’s summary.  A correction: P1 is missing in classified performance impact on Coverage. |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Intel | Y | With the disclaimer than many of the items in the list may not be relevant unless the switching times are significantly long compared to typical scheduling durations (e.g., slot). |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.4.3-2: Which of the identified performance impacts in the list above (P1, P2, …, P12) are the most critical ones to be captured in TR 38.875 for HD-FDD?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1, P2 |
| FUTUREWEI | Should include:P1,P2,P4, P6,P7,P8,P9,P10,P11  No strong feeling: P3, P5, P12  Should not include:  P11 |
| Ericsson | P1, P3, P7, P12 |
| Sierra Wireless | P1, P2, P3, P4, P7 |
| Spreadtrum | P2, P4 |
| ZTE,Sanechips | P1,P2,P7 |
| Samsung | P1, P2, P3, P7, P9, P11, P12 |
| Xiaomi | P2, P4, P9, P12 |
| Huawei, HiSilicon | Except for P2, P3 and P12.  HD-FDD is studied for cost reduction and associated impact on e.g. data rate, as stated in SID. Thus, P2 and P3 are not critical. P12 may need further verification as not clear about the reliability aspect. |
| Sequans | P2-P6, P7 for Type A, P8-P11, FFS for P12 |
| Lenovo, Motorola Mobility | P1, P3, P7 |
| Intel | P1, P2, P3, P4, P11 (under the assumption that switching gaps are not significantly long compared to typical scheduling time granularity) |
| Nokia, NSB | P1, P2, P3, P4, P7, P9 |
| MediaTek | P1, P2, P4, P7, P9, P11 |
| Qualcomm | P1, P2, P3, P7, P11, P12 |

### 7.4.4 Analysis of coexistence with legacy UEs

Contributions [1, 2, 3, 5, 7, 17, 25] analyze coexistence impacts. The identified issues are listed below.

* C1: significant impact on network [2]
* C2: make scheduler more complex [3]
* C3: need to monitor PI/CI to ensure coexistence with URLLC UEs [7]

Contributions [1, 5, 17, 25] conclude that the impact can be minimal or do not raise a concern.

**Q 7.4.4-1: Does the list above (C1, C2, C3) capture the most important coexistence impacts that need to be considered for HD-FDD? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y |  |
| Ericsson | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | N | C4= ‘no significant impact’ |
| Samsung | N | May have co-existence issue with legacy UE due to switching time from PRACH to Msg2, depending on the configuration and gap.  C1 to C3 need to be further discussed |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | N | None is well justified. |

**Q 7.4.4-2: Which of the identified coexistence impacts in the list above (C1, C2, C3) are the most critical ones to be captured in TR 38.875 for HD-FDD?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | C1, C2 |
| FUTUREWEI | C1, C2 should be included. Not sure about C3. |
| Ericsson | Possibly C2. However, if it is done properly, the impact on scheduler might be minor. |
| Sierra Wireless | C2 |
| ZTE,Sanechips | C2 |
| Xiaomi | None |
| Huawei, HiSilicon | all |
| Sequans | C1, C2, FFS for C3 |
| Lenovo, Motorola Mobility | Possibly C2. |
| Intel | None (under the assumption that switching gaps are not significantly long compared to typical scheduling time granularity) |
| Nokia, NSB | C2 |
| MediaTek | Agree with Ericsson. |
| Qualcomm | Minor impacts on scheduler |

### 7.4.5 Analysis of specification impacts

Contributions [1, 3, 4, 5, 6, 7, 9, 10, 12, 15, 17, 20, 22, 23, 25, 26, 29, 30] identify specification impacts listed below.

* S1: DL-to-UL and/or UL-to-DL switching time [3, 4, 5, 6, 7, 9, 12, 15, 17, 20, 22, 29, 30]
* S2: rule for handling DL/UL collision [1, 12, 26]
* S3: applicable bands and perf requirements [1, 3, 17]
* S4: capability signaling [5, 7, 25]
* S5: DL pre-emption and UL cancellation; Prioritization between eMBB traffic and URLLC traffic [7]
* S6: definition of HD-FDD operation type [20]
* S7: impact of BWP adaptation [10]
* S8: Type B HD-FDD may result in some necessary changes in the L1 design [23]
* S9: HARQ ACK/NACK bundling [29]
* S10: RRC configuration of UL and DL slots/symbols similar to NR TDD [29]

Regarding DL-to-UL and/or UL-to-DL switching time, contributions [1, 4] state that the transition time and the scheduling restriction defined for a UE not capable of full duplex in Rel-15 can be used as a baseline, whereas contribution [12] suggests that more relaxed switching time may be considered.

Contributions [9, 22, 30] suggest a DL-to-UL switching time may be created by not receiving symbols at the end of the DL slot immediately preceding the uplink transmission slot. Contributions [9, 20, 22, 30] suggest the switching time of uplink-to-downlink transition can be created by properly setting TA value by gNB scheduler for the RedCap devices without the need of special handing. Contribution [26] suggests symbol-level switching time.

Contributions [6, 7, 25] conclude that the overall specification impact is small.

**Q 7.4.5-1: Does the list above (S1, S2, …, S10) capture the most important specifications impacts that need to be considered for HD-FDD? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | Y |  |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | Y |  |
| Samsung |  | Some of the above list needs to be further discussed.  We suggest to identify the issue first and then categorize the solutions for the issues. Some solutions can be combined. |
| Xiaomi | Y | We agree on FL’s summary. In our contribution [15] we also propose that gNB should be able to configure UL/DL slots/symbols for HD-FDD UE. |
| Huawei, HiSilicon | N | Not pursued |
| Sequans | Yes | As a list of possible impact when introduced |
| Lenovo, Motorola Mobility | Y |  |
| Nokia, NSB | Y |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.4.5-2: Which of the identified specification impacts in the list above (S1, S2, …, S10) are the most critical ones to be captured in TR 38.875 for HD-FDD?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1, S5 |
| FUTUREWEI | Should include: S1,S3,S4  No strong feeling:S6,S10  Should not include:S2,S5 (not sure), S7, S9  S8 will depend on Type B being included in the TR |
| Ericsson | S1, S2, S3, S4, S6  S8 if Type B is adopted.  S5 deserves further discussion |
| Sierra Wireless | S1, S3, S4 |
| Spreadtrum | S1, S6 |
| ZTE,Sanechips | S1, S3, S6 |
| Samsung | We suggest to identify the issue first and then categorize the solutions for the issues. Some solutions can be combined.  S1, S2, S8 |
| Xiaomi | S1, S2, S4, S10 |
| Sequans | At least S1-S4 |
| Lenovo, Motorola Mobility | S1, S3, S4, S6 |
| Intel | At this point, only S1, S2, S3, S4, S6 |
| Nokia, NSB | S1, S2, S3, S4 |
| MediaTek | S1, S2, S4, S6 |
| Qualcomm | S1, S2, S4, S6, S9, S10 |

## 7.5 Relaxed UE processing time

### 7.5.1 Description of feature

In RAN1#101-e, the agreement was made to study UE complexity reduction through a more relaxed UE processing time in terms of N1/N2.

|  |
| --- |
| Agreements:   * For UE complexity reduction through relaxed UE processing time, study a more relaxed UE processing time in terms of N1/N2 compared to capability #1. |

Many contributions [1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 16, 17, 19, 20, 21, 27, 29, 31] discuss relaxed UE processing time in terms of N1/N2 and provide analyses on different aspects as summarized in the next subsections. For the continued evaluation, it might be useful to agree on what values of N1 and N2 to assume. For example, contribution [6] assumed that N1 and N2 were doubled.

**Q 7.5.1-1: For the evaluation of relaxed UE processing time in terms of N1/N2, what values of N1 and N2 should be assumed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | Doubling is OK to include as an example. Can also include specifically the Rel-16 cross-slot scheduling as another example, though this will also be mentioned in power savings.  Both have a similarly small benefit in terms of cost reduction, but very different impacts in design effort and specification. |
| SONY | N1 / N2 doubled. We don’t have a strong preference on the scaling factor, but think that we need a concrete scaling factor in order to derive conclusions. |
| Ericsson | For the purpose of evaluation and simplicity, N1 and N2 can be assumed to be doubled from those of capability #1. |
| DOCOMO | Doubled N1/N2 |
| InterDigital | N1 and N2 can be doubled. |
| Spreadtrum | For simplicity, N1 and N2 can be assumed to be doubled from those of capability #1. |
| ZTE,Sanechips | Doubled N1/N2 |
| Sharp | For evaluation, the doubled value of N1/N2 can be assumed as a starting point. |
| vivo | Doubled N1 and N2 from Cap#1 UEs, or further relaxed to LTE UE processing time. |
| Samsung | Double N1 and N2 can be assumed for the analysis |
| LG | Doubling N1 and N2 can be a good starting point. |
| OPPO | Doubled N1/N2 |
| CMCC | Doubled N1/N2 |
| Huawei, HiSilicon | FFS. It has not been well justified how this would obviously reduce the cost. For example there is quite different value observed from the table in section 7.5.2 for some component, e.g. range can be 0%~40% for DL control processing & decoder. |
| Sequans | Doubled N1/N2 seems OK to study |
| Lenovo, Motorola Mobility | Could double N1/N2 for evaluation purpose. |
| Intel | Fine with considering doubled N1/N2 values as starting point. |
| Nokia, NSB | Doubled N1/N2 |
| MediaTek | Doubled N1/N2. |
| Qualcomm | Relaxed UE processing time should be jointly studied with UE power saving. For the simplicity of analysis, doubling the length of N1/N2 can be assumed. |
| FL | For the evaluation of relaxed UE processing time in terms of N1/N2, most companies share the view that values of N1 and N2 can be assumed to be doubled compared to those of capability #1.  Proposal:   * For the purpose of evaluation, the UE processing time in terms of N1/N2 can be 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 |

Some contributions [2, 12, 17, 27, 29] also mention that CSI computation time can be included as part of the study on relaxed UE processing time.

**Q 7.5.1-2: In addition to relaxed UE processing time in terms of N1/N2, should the study include analysis of relaxed UE processing time related to CSI computation?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| FUTUREWEI |  | No strong feeling |
| SONY | Yes | We are OK studying this, but it is not a priority for us. |
| Ericsson | No | The CSI processing complexity may anyway be reduced due to other cost reduction aspects, e.g. bandwidth reduction. |
| DOCOMO | No | We are fine to study, but as observed from the evaluation of relaxed UE processing time in terms of N1/N2, the complexity reduction is not significant by the relaxed UE processing time while it would cause significant impact on the performance. In that sense, the analysis of relaxed CSI computation time should not be prioritized. |
| InterDigital | Yes. |  |
| ZTE,Sanechips | Y |  |
| Panasonic | N | There is no need to study it within Red Cap SI. If coverage enhancement SI captures some technique, it can be applied to RedCap. |
| vivo |  | Can be deprioritized in the SI phase. |
| Samsung |  | No strong view. But if Z cannot be relaxed, it may not provide complexity gain for N1/N2.  Similarly, double Z can be assumed. |
| LG |  | Don’t have a strong view. |
| OPPO |  | No strong views, can be studied |
| CMCC |  | We are fine to study it. |
| Huawei, HiSilicon | Y | Equivalent study to that for N1/N2 |
| Sequans |  | No strong view |
| Lenovo, Motorola Mobility | No |  |
| Intel | Y | Burden on UE for CSI computation can be significantly relaxed – either or both of reporting metrics and associated processing times. |
| Nokia, NSB | N |  |
| MediaTek | N | Agree with Docomo’s arguments on deprioritizing CSI timeline. |
| Qualcomm | Yes | With lower priority. |
| FL |  | There are mixed views on whether CSI computation relaxation should be studied.  Proposal:   * Study of relaxed UE processing time related to CSI computation is not prioritized in the RedCap study item. |

### 7.5.2 Analysis of UE complexity reduction

Many contributions [1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 16, 17, 19, 20, 21, 27, 29, 31] discuss potential UE complexity reduction from relaxed UE processing time in terms of N1/N2. Some arguments are based on possible slower processor with reduced clock frequency, possible distribution of computation load over time, possible reduced demands on parallel processing and chip area, and possible less complex channel decoder.

Some contributions also provide analysis of the cost reduction based on estimate of the cost breakdown of different processing components [6, 17, 20]. Contributions [1, 6, 17, 20, 27] identify that the cost reduction may come from reduced baseband processing, especially from receiver processing block including LDPC decoding and DL control processing & decoder, and UL processing block.

Some cost reduction estimates for relaxed UE processing time are shown in the table below. As can be seen in the rightmost column, the overall estimated cost reduction is 5% according to [3], around 2% according to [6], 1.5-2.6% for relaxed N2 (doubled) and 6.42-9.63% for relaxed N1 (doubled) according to [17], and up to 7% according to [20]. Contribution [3] further notes that the complexity reduction will not accumulate over multiple bands.

Table 1: Estimate cost/complexity reduction from a more relaxed N1/N2 compared to Capability #1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Contribution** | **Cost reduction in baseband parts** | | | | **Total of Baseband relative cost reduction[[1]](#footnote-2)** | **Overall relative cost reduction[[2]](#footnote-3)** |
| **Receiver processing block** | **LDPC decoding** | **DL control processing & decoder** | **UL processing block** |
| **[3]** |  |  |  |  |  | **<5%** |
| **[6]** | 0% | 20% | 0% | 20% | 3% | **2%** |
| **[17]** | ~50%? | ~50%? | 0% | ~50%? | (19.75%) | **FR1 (FDD): N1: 9.63%, N2: 2.6%**  **FR1 (TDD): N1: 8%, N2: 1.88%**  **FR2 (TDD): N1: 6.42%, N2: 1.5%** |
| **[20]** | 25% | 20% | 40% | 25% | 11.15% | **6.69%** |

Contributions [1, 5, 27] note that the actual complexity/cost reduction may not be clear as it depends on the specific implementation. Some contributions [6, 8] suggest that the complexity/cost reduction might be rather small compared to the required standardization efforts and impacts described in the following sections.

Contributions [1, 8, 17, 27] emphasize that the cost/complexity reduction would be limited or reduced significantly when it is considered on top of other UE complexity reduction features.

### 7.5.3 Analysis of performance impacts

Contributions [1, 2, 3, 4, 5, 6, 8, 11, 13, 16, 17, 20, 27, 29, 31] analyze the performance impact if relaxed UE processing time is introduced for RedCap UEs. The findings are listed below.

**Latency:**

* P1: Contributions [1, 2, 5, 8, 11, 13, 20, 27] mentioned the impact of relaxed UE processing time capability on latency, where [1, 5] provide some numerical examples of the impact on UL and DL latency for the initial transmission and different number of retransmissions.
* P2: Contributions [1, 2, 4, 16, 20, 27, 29, 31] 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, 3, 8, 20, 27] 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.
* P4: Contribution [13] discusses an implication of relaxed UE processing time on latency which can lead to having different hardware variants for RedCap UEs.

**Scheduling flexibility/complexity:**

* P5: Contributions [1, 2, 8, 17] observe negative impacts of relaxed UE processing time on scheduling complexity, especially when taking into account different scheduling timing requirements related to N1/N2 and the fact that there already exist two UE processing time capabilities in NR.

**Data rate:**

* P6: Contributions [2, 3] mention that sustained data rate may be impacted due to longer HARQ RTT because of the relaxed UE processing time.

**Coverage:**

* P7: Contributions [3, 6, 17] note that no significant coverage impact is expected from a more relaxed UE processing time.

**Spectral efficiency/network capacity:**

* P8: Contributions [6, 17] note that no impact on spectral efficiency or network capacity is expected since gNB can schedule other UEs during the UE processing time.

**Power consumption:**

* P9: Contributions [2, 4, 16, 29, 31] mentioned that power saving benefit can be obtained from relaxed UE processing time, particularly from cross-slot scheduling which may lower UE’s working voltage and avoiding unnecessary data buffering.
* P10: Contributions [1, 5, 6, 20, 27] 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 cross-slot scheduling can be supported by gNB implementation without the need to introduce a more relaxed UE processing time capability.

**Q 7.5.3-1: Does the list (P1, P2, …, P11) above capture the most important performance impacts that need to be considered for relaxed UE processing time? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | For cross-slot scheduling, need to state there is no real impact to latency, scheduling, data rate, coverage, spectral efficiency. Plus P9,11 |
| Ericsson | Y |  |
| Sierra Wireless | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | Y |  |
| vivo |  | For latency: the latency requirement is use case dependent, so both P2 and P3 can be true in different scenarios  For scheduling: we think gNB should be able to manage different scheduling timelines.  For data rate: there should be no problem if we do not consider lower than the LTE processing capability  Coverage: agree with P7  Spectrum efficiency/capacity: agree with P8  Power consumption: agree with P9  In addition to above, another possibility is that we do not lower the UE capability, i.e. UE still capable of Cap#1 timeline, but network can configure the UE with slower timeline to achieve power saving gain. |
| Samsung |  | To align whether to add coverage analysis with other features.  Some in the above list need to be further discussed. |
| OPPO | Y |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sequans | Yes |  |
| Lenovo, Motorola Mobility | Y |  |
| Nokia, NSB | N |  |
| MediaTek | Y |  |
| Qualcomm | Y |  |

**Q 7.5.3-2: Which of the identified performance impacts in the list above (P1, P2, …, P11) are the most critical ones to be captured in TR 38.875 for relaxed UE processing time?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1, P2 |
| FUTUREWEI | For e.g. doubling N1/N2:  Should include: P3, P4, P5, P6, P10  No strong feeling:P1, P2, P7  Should not include:P8 (scheduling may need to be more conservative), P9 (as P10 is correct)  For cross-slot scheduling: P9, P11 |
| Ericsson | P1-P11 |
| Sierra Wireless | P1, P3, P4, P5, P6, P7, P10 |
| Spreadtrum | P1, P2, P3, P10 |
| ZTE,Sanechips | P1, P2, P3, P5, P9,P10 |
| vivo | P2/7/8/9 |
| Samsung | P1, P3, P5, P8, P10 |
| OPPO | P2/7/8/9 |
| CMCC | P1, P2, P3, P5 |
| Huawei, HiSilicon | Can be further studied. |
| Sequans | P1-P6, P10 |
| Lenovo, Motorola Mobility | P2, P6, P7, P8, P10, P11 |
| Intel | P2, P3, P6, P7, P9, P11.  On P5: The additional scheduler complexity compared to all the different minimum processing times and various conditions and margins we have is negligible.  On P10: To properly evaluate the net effect, potential updates to the power consumption model would be necessary to factor lower power consumption from reduced demands on parallelization, working voltage, and chip area. |
| Nokia, NSB | P1-P4, P6, P7, P8, P10 |
| MediaTek | P1-P6 |
| Qualcomm | P2, P3, P6, P7, P9, P10, P11 |

### 7.5.4 Analysis of coexistence with legacy UEs

Some contributions [1, 5, 17, 21] 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. Contribution [3] notes that multiple timelines can be very complicated to specify and handle to ensure coexistence with legacy UEs.

In order to support relaxed UE processing time capability during initial access, contributions [5, 12, 21] mention that methods for identifying RedCap UEs, e.g., before Msg3 scheduling may need to be studied.

These identified issues are listed below.

* C1: makes scheduler more complex [1, 5, 17, 21]
* C2: complicated to specify and handle to ensure coexistence with legacy UEs [3]
* C3: identification of RedCap UEs before Msg3 may be needed [5, 12, 21]

**Q 7.5.4-1: Is the list of identified coexistence issues to study for relaxed UE processing time in terms of N1/N2 correct and complete? If not, what changes to the list are needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | OK |
| Ericsson | Yes |
| Sierra Wireless | Yes |
| ZTE,Sanechips | Y |
| vivo | We agree that C3 would need to be discussed if lower processing capability UE is introduced. |
| Samsung | OK. |
| OPPO | Y |
| CMCC | Yes |
| Huawei, HiSilicon | Y |
| Sequans | Yes |
| Lenovo, Motorola Mobility | Yes |
| Intel | Yes to C1 and C3. Do not agree to C2 in general.  Also, this statement is misleading “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.” By this logic, Cap #2 is a useless feature as long as there is a single Cap #1-only UE in the system. |
| Nokia, NSB | Y |
| MediaTek | Y |
| Qualcomm | Yes |

**Q 7.5.4-2: Which of the identified coexistence issues in the list above (C1, C2, C3) are the most critical ones to be captured in TR 38.875 for relaxed UE processing time in terms of N1/N2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | C1 |
| FUTUREWEI | Should include C1 and C2. C3 may be ok, FFS. |
| Ericsson | C1-C3 |
| Sierra Wireless | C1, C2, C3 |
| ZTE,Sanechips | C1, C3 |
| vivo | C3 |
| Samsung | C1, C3 |
| OPPO | C3 |
| CMCC | C1,C3 |
| Huawei, HiSilicon | all |
| Sequans | C1-C3 |
| Lenovo, Motorola Mobility | C1, C3 |
| Intel | C1, C3 |
| Nokia, NSB | C1, C2, C3 |
| MediaTek | C1,C2,C3 |
| Qualcomm | C1, C3. FFS C2. |

### 7.5.5 Analysis of specification impacts

Contributions [1, 2, 3, 6, 17, 20] mention the specification impact of defining a new relaxed UE processing time capability and new values of N1/N2. Contributions [3, 8] 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, 17, 19]. On the other hand, contribution [1] notes that no specification impacts on scheduling timing and HARQ-ACK timing 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, 6, 8, 17, 20]
* S2: scheduling time related to default TDRA tables and HARQ-ACK timing range [5, 17, 19]

**Q 7.5.5-1: Is the list of identified specification impacts to study for relaxed UE processing time in terms of N1/N2 correct and complete? If not, what changes to the list are needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | There are likely other impacts that these related to coexistence and handling multiple timelines |
| Ericsson | In addition, some timing aspects during the random access procedure may need to be clarified. |
| ZTE,Sanechips | Y |
| vivo | We think S1 is more important. Regarding S2, we do not expect the relaxation of N1/N2 would require additional value range for K1/K2 as the existing value range is already wide enough. |
| Samsung | Some of the above list needs to be further discussed.  We suggest to identify the issue first and then categorize the solutions for the issues. Some solutions can be combined |
| OPPO | Y |
| CMCC | Y |
| Huawei, HiSilicon | A bit early to conclude but open to discuss. |
| Sequans | Yes |
| Lenovo, Motorola Mobility | Yes |
| Nokia, NSB | Y |
| MediaTek | FFS |
| Qualcomm | Yes |

**Q 7.5.5-2: Which of the identified specification impacts in the list above (S1, S2) are the most critical ones to be captured in TR 38.875 for relaxed UE processing time in terms of N1/N2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1 |
| FUTUREWEI | S1. S2 (FFS). |
| Ericsson | S1  Regarding S2, TDRA values in the specs can already accommodate relaxed N1/N2. |
| Spreadtrum | S1, S2 |
| ZTE,Sanechips | S1 |
| vivo | S1 |
| Samsung | S1 |
| OPPO | S1 |
| CMCC | S1,S2 |
| Huawei, HiSilicon | Open to further discuss. |
| Sequans | S1, FFS S2 |
| Lenovo, Motorola Mobility | S1, S2. |
| Intel | S1. |
| Nokia, NSB | S1 |
| MediaTek | FFS |
| Qualcomm | S1. FFS S2 |

## 7.6 Relaxed UE processing capability

### 7.6.1 Description of feature

In RAN1#101-e, consensus could not be reached whether relaxed UE processing capability should be studied and which techniques to study. Several techniques are discussed and proposed again. The main discussions are mostly on restricting the maximum modulation orders, the maximum number of MIMO layers, TB sizes and reducing the maximum number of HARQ processes.

***General***

A few contributions [1, 17] indicate that after bandwidth and antenna reductions, significant cost saving gains would not be expected via other complexity reduction techniques. One contribution [3] notes there will only be little benefit in cost/complexity reduction for reduced TBS or HARQ after bandwidth reduction and modulation order restriction. Another contribution [17] further indicates studies on the four techniques for complexity reduction are not necessary.

Contributions [1, 8, 17] indicate cost saving from bandwidth reduction and antenna reductions should not be double counted in cost saving by restricting the maximum TB sizes and the maximum number of MIMO layers.

A few contributions [13, 19, 27] indicates peak rate impacts due to different TDD patterns.

One contribution [27] proposes to agree on whether peak rates less than 150MHz DL and 50MHz UL can be considered. One contribution [5] states that the maximum modulation order and the maximum number of MIMO layers should be specified based on the requirements of peak data rate.

***Maximum modulation order and maximum number of MIMO layers***

Many contributions [1, 2, 3, 4, 5, 6, 11, 12, 13, 16, 18, 20, 23, 27, 29, 30] indicate reducing restricted modulation order can provide complexity reduction or can be studied. One contribution [3] further notes that the gains from restricting the maximum modulation order would accumulate over the multiple RF bands typically present in a device, in contrast to the other baseband-oriented techniques.

Several contributions [1, 3, 5, 11, 12, 16, 20, 23, 27, 30] also indicate MIMO reductions can be studied.

One contribution [3] further indicates only either restricting the maximum number of MIMO layers or modulation order should be studied, while another contribution [23] notes that both techniques should be studied together to understand the trade-offs between both techniques.

***Restricting the TB sizes***

A few contributions [1, 3, 17, 18] indicate that TBS in NR are calculation based and would be reduced significantly after reduction in bandwidth, antenna and modulation order. Therefore, it is not necessary to study restricting the maximum TB sizes.

Some contributions [2, 12, 16, 23, 29, 30] however indicates TBS reduction can be studied.

***Reducing the maximum number of HARQ processes***

A few contributions [1, 2, 3, 17] indicate soft buffer size saving via reducing the number of HARQ processes are insignificant or the gain is unclear as the HARQ process partition is up to UE implementation in NR. Furthermore, a few contributions [1, 2, 8] argue that reducing the number of HARQ processes will impact sustainable peak rates and the number of HARQ processes should not be reduced for RedCap devices.

One contribution [8] indicate it can be beneficial to cap the maximum soft channel bits without reducing the maximum number of HARQ processes.

Some contributions [4, 11, 16, 20, 29, 30] note that reducing the number of HARQ processes is beneficial for low cost devices and can be studied.

***Other techniques***

Two contributions [12, 27] indicate maximum number of DL CC could be limited and one contribution [27] notes that at least intra-band carrier aggregation shall be studied. One contribution [19] indicate UL MIMO, UL CA or SUL can be studied to achieve higher peak data rate. Contribution [2, 27] note that SUL can be studied to achieve larger coverage and UL CA shall not be supported. One contribution [27] notes that CA/SUL shall be considered together with the maximum BW study. However, contribution [29] highlights certain issues with SUL.

Some other contributions [4, 23, 29] indicate support of carrier aggregation are not required or restricted for RedCap devices or shall be single carrier support only.

A few contributions [5, 12, 16, 27, 29, 30] further indicate other techniques listed below can be studied:

* OFDM as an optional waveform for RedCap devices [12, 30]
* Simplification of CSI measurements/feedback [5, 27, 29]
* Simplified beam management framework [27, 29]
* Simplified BWP switching delay [16]
* Reduced HARQ ACK/NACK bundling [29]
* Reduced PDCCH monitoring capability (i.e. relaxed maximum number of BDs and/or CCEs) [16, 27, 29]
* Reducing the number of PRBs allocated for PDSCH/PUSCH [29] [20]
* Restricting the maximum code rate [29]
* Simplified TA validation for stationary or low-mobility UE [29]
* Simplified RLM/RRM measurements [29]
* Simplified BWP operation [12]
* No support of simultaneous reception [12]
* No support of prioritization of dynamically scheduled PDSCH/PUSCH over SPS/CG PUSCH occasions respectively [12]
* PDSCH reception with receiver side puncturing on configured reserved resources [12]
* Reduced number of CSI-RS antenna ports and number of parallel CSI report processing compared to Rel-15 [12]
* No dynamic indication of TCI state for PDCCH and PDSCH [12]

**Q 7.6.1-1: What, if any, modulation scheme restrictions should be considered?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | Either none, or optional 256QAM in DL and 64QAM in UL for FR1 |
| SONY | Max modulation = 64QAM. Modulation scheme restrictions are not a priority item for us. |
| Ericsson | FR1& FR2: Both UL and DL restricted to QPSK, 16QAM, and 64QAM  Further restriction to QPSK and 16QAM in FR2 might be considered. |
| Sierra Wireless | Can consider reducing modulation scheme to 64QAM DL and 16QAM UL for FR1 |
| DOCOMO | As the complexity reduction by modulation scheme restriction is not significant while the impact on performance is not negligible, we don’t think modulation scheme restriction is prioritized. |
| InterDigital | 64 QAM can be considered as max. modulation for FR1. For FR2, further restriction to max. 16 QAM can be considered. |
| Spreadtrum | 256QAM should be optional for DL. 64QAM should be optional for UL. |
| ZTE,Sanechips | DL : only 16QAM and 64QAM; UL: 16QAM |
| Sharp | Maximum 64QAM for DL and UL. |
| Panasonic | FR1 DL: Up to 64QAM  FR1 UL: Up to 16QAM  FR2 DL: Up to 64QAM. Up to QPSK or 16QAM can be considered.  FR2 UL: Up to QPSK. Only BPSK can also be considered. |
| vivo | 256QAM in DL and 64QAM in UL should be optional for Redcap UEs. |
| Samsung | Based on the analysis, there is no need to restrict the modulation scheme. |
| LG | 64QAM for high-end wearables and 16QAM for low-end devices (sensors, surveillance camera, low-end wearables etc.). The restrictions can be defined per device type, if supported. |
| OPPO | 256QAM in DL and 64QAM in UL should be optional for Redcap UEs. |
| CMCC | 256QAM in DL and 64QAM in UL to achieve peak data rate in TDD. |
| Huawei, HiSilicon | Max 64QAM for both UL and DL for FR1. |
| Sequans | No strong view |
| Lenovo, Motorola Mobility | For FR1, 64QAM for both DL and UL  For FR2, 64QAM for DL, 16QAM for UL |
| Intel | FR1& FR2: Both UL and DL restricted to QPSK, 16QAM, and 64QAM |
| Nokia, NSB | 64-QAM for the DL, 16-QAM for the UL |
| MediaTek | None. 256qam/64qam DL/UL can improve efficiency and are necessary for throughput in high-end scenarios. |
| Qualcomm | For FR1, 64QAM on DL/UL.  FFS: for FR2, 16-QAM or 64-QAM on DL/UL |
| FL | Most of the responses want to consider restricting the FR1 DL modulation to max 64QAM. Almost half of the responses want to consider restricting the FR1 UL modulation to 16QAM. Most of the responses did not mention FR2, but those who did mention FR2 expressed an interest in considering restriction of the modulation to 16QAM in DL and/or UL. A few responses do not want to consider any restriction of the modulation.  Proposal:   * For FR1 DL, study restriction of modulation scheme to max 64QAM. * For FR1 UL, study restriction of modulation scheme to max 16QAM.   Proposal:   * For FR2 DL, study restriction of modulation scheme to max 16QAM. * For FR2 UL, study restriction of modulation scheme to max 16QAM. |

**Q 7.6.1-2: What, if any, MIMO layer restrictions should be considered?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | Either none, or single layer in a 2RX RedCap UE |
| SONY | Max MIMO layers = number of antennas. |
| Ericsson | 1 or 2 MIMO layers in DL might be considered |
| Sierra Wireless | None. |
| DOCOMO | We think MIMO layer restriction resulting from reduced number of Tx/Rx is sufficient. |
| InterDigital | 1 or 2 layers. |
| Spreadtrum | Only up to 2 MIMO layers can be supported. |
| ZTE,Sanechips | 1 or 2 layer depending on UE capability |
| Sharp | One or two MIMO layers can be considered. At least two layers is necessary to meet the 150M peak data rate for FR1 if the maximum modulation scheme is limited to 64QAM. |
| Panasonic | Up to 2 MIMO layers for FR1 DL, 1 MIMO layer for FR1 UL and FR2 |
| vivo | We think MIMO layer restriction can be supported for 2Rx capable RedCap UEs. |
| Samsung | No need to further restrict MIMO layer if the number of antenna is reduced. |
| LG | Two layers for high-end wearables and one layer for low-end devices (sensors, surveillance camera, low-end wearables etc.). The restrictions can be defined per device type, if supported. |
| OPPO | 1 or 2 layer depending on UE capability |
| CMCC | Yes, 2 layers for 2Rx RedCap UEs |
| Huawei, HiSilicon | 2 for DL and 1 for UL.  Should clarify that MIMO-layers may be more about a baseband capability that reflects chipset design, while with 2-layers in BB, 1Rx can be implemented. Whether to support 1Rx is not equivalent to whether to agree on single MIMO layer from hardware perspective. |
| Sequans | 1 or 2 MIMO layers |
| Lenovo, Motorola Mobility | 1 or 2 MIMO layer in DL with 2Rx antennas. |
| Intel | 1 MIMO layer as baseline.  FFS: 2 MIMO layers as optional capability. |
| Nokia, NSB | 1 or 2 layers, depending on number of Rx antennas |
| MediaTek | 2 for DL and 1 for UL. Agree with Huawei’s point that “Whether to support 1Rx is not equivalent to whether to agree on single MIMO layer from hardware perspective.” |
| Qualcomm | UL: single MIMO layer only.  DL:  • Single MIMO layer in FDD bands of FR1.  • Single MIMO layer for RedCap UE with device size limitation.  • One or two MIMO layers for RedCap UE with 2 RX antennas. |
| FL | Most of the responses express an interest in considering 1 and 2 MIMO layers in DL for both FR1 and FR2.  Proposal:   * Restriction to 1 and 2 MIMO layers in DL can be studied for both FR1 and FR2. |

**Q 7.6.1-3: Should any explicit TBS restrictions be considered beyond the implicit TBS restrictions resulting from reduced UE bandwidth and reduced number of antennas?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | No |
| SONY | Yes. We would like to consider a fixed max TBS (rather than one worked out through equations). However, we think that some of the complexity reduction techniques will lead to a TBS that is less than the “fixed max TBS” in any case. |
| Ericsson | No |
| Sierra Wireless | No |
| DOCOMO | Not necessary to consider explicit TBS restriction. That resulting from reduced UE BW and reduced number of Tx/Rx is sufficient. |
| InterDigital | No. |
| ZTE,Sanechips | Cam be low priority |
| Sharp | No. Implicit TBS restriction is sufficient. |
| Panasonic | No need to study it. On the other hand, in work item phase, the discussion to introduce new scaling factor should not be precluded. |
| vivo | No strong view. |
| Samsung | No. |
| LG | No. |
| OPPO | Can be considered |
| CMCC | No |
| Huawei, HiSilicon | N |
| Sequans | Can be considered, as second priority after MIMO layer restriction considerations |
| Lenovo, Motorola Mobility | No |
| Intel | TBS reduction (on top of BW, modulation order, # of MIMO layers) can be beneficial for UEs with low data rate requirements since 20 MHz and 64QAM already leads to rather large TB sizes compared to peak rate requirements for some of the identified RedCap use-cases. Such TBS reduction could be defined as optional feature instead of baseline. |
| Nokia, NSB | Yes, for low-end RedCap UE type if such type is defined |
| MediaTek | Could be considered for 100 MHz BW option in FR2. |
| Qualcomm | No |
| FL | Most of the responses express that explicit TBS restriction beyond the implicit TBS restrictions resulting from reduced UE bandwidth and reduced number of antennas should not be studied.  Proposal:   * No TBS restriction is considered beyond the implicit TBS restrictions resulting from reduced UE bandwidth and reduced number of antennas. |

**Q 7.6.1-4: What, if any, HARQ restrictions should be considered?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | None |
| SONY | Number of HARQ processes should not be reduced. Can consider reduction of soft buffer sizes. |
| Ericsson | No |
| DOCOMO | As the complexity reduction by HARQ restriction is not significant while the impact on performance is not negligible, we don’t think any HARQ restriction is necessary. |
| InterDigital | None. |
| ZTE,Sanechips | No |
| Sharp | No |
| Panasonic | No |
| vivo | We think RedCap UEs should be allowed to support less HARQ processes. |
| Samsung | If this is UE implementation, no need to reduce the HARQ process number. If supported, 8 HARQ processes can be considered. |
| LG | No. |
| OPPO | NO |
| CMCC | No |
| Huawei, HiSilicon | N |
| Sequans | We think no, but not strong view. |
| Lenovo, Motorola Mobility | No |
| Nokia, NSB | N |
| MediaTek | None |
| Qualcomm | Reduced number of HARQ processes with relaxation on HARQ RTT. |
| FL | All responses expect for two express that no HARQ restrictions should be considered.  Proposal:   * No HARQ restrictions are considered further in the study. |

**Q 7.6.1-5: Among all the items mentioned under the heading of “Other techniques”, which ones (if any) should be considered?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | None |
| Ericsson | None |
| Sierra Wireless | None |
| Spreadtrum | Reducing the number of PRBs allocated for PDSCH/PUSCH. |
| ZTE,Sanechips | None |
| Samsung | None |
| CMCC | UL MIMO, UL CA or SUL can be studied to achieve higher peak data rate in TDD. |
| Huawei, HiSilicon | N |
| Sequans | CSI measurements/feedback simplification. We think that the measurement procedures and CSI feedback may have significant share in the complexity on the BBIC side and worth some further study.  Also CA/SUL (at least intra-band) |
| Lenovo, Motorola Mobility | None |
| Intel | At least the following should be considered further:   * DL intra-band CA should be considered as an optional capability targeting high DL peak rate requirements. * Simplification of CSI measurements/feedback |
| Nokia, NSB | None |
| MediaTek | None |
| Qualcomm | We think the following techniques can be further studied: simplified beam management framework, simplified BWP switching with reduced delay, simplified BFR/BFD/RLM/RRM measurements. |

### 7.6.2 Analysis of UE complexity reduction

|  |  |  |
| --- | --- | --- |
| **Techniques** | **Impacted components** | **Cost saving** |
| Reduced maximum number of MIMO layers | Baseband:  FFT/IFFT [17, 30]  Post-FFT data buffering [17, 30]  Receiver processing block [1, 17, 20, 30]  LDPC decoding [1, 5, 17, 20]  HARQ buffer [1, 17, 20]  Synchronization / cell search block [17, 30]  MIMO specific processing blocks: [1, 5, 17]  DMRS channel estimation [5]  Demodulation with less MIMO layers [5]  No layer de-mapping [5] | Form 2 -> 1 MIMO layer, 4 -> 2MIMO layers  Source 1 [1]: marginal total cost saving  Source 2 [17]: 17.5% - 32.8% total complexity saving  Source 3 [20]: 18.9% total cost saving  Source 5 [30]: 22% baseband cost saving  From 4 -> 1 MMIO layer:  Source 1 [1]: medium to significant total gain.  Source 3 [20]: 28.35% total cost saving |
| Restricted maximum modulation order | RF components:  PA: [1, 6, 17, 20]  RF transceiver [1, 17, 20]  Baseband components:  ADC: [1, 6]  Post-FFT data buffering: [1]  LDCP decoding: [6, 30]  HARQ buffer: [6]  UL processing block: [6] | 256QAM->64QAM:  Source 1 [1]: 0-5% RF cost saving gain and 3-4% baseband cost saving gain  xQAM -> yQAM:  Source 2 [17]: ~1% total cost saving  Source 3 [20]: 9.6% total cost saving  Source 5 [30]: 5% baseband cost saving  256QAM->64QAM in DL and 64QAM->16QAM in UL  Source 4 [6]: 6% total cost saving |
| Reduced number of HARQ process | Baseband components:  HARQ buffer: [1, 17, 20, 30]  UL processing block: [20] | Source 2 [17]: unclear UE implementation  16 -> 8 HARQ processes  Source 1 [1]: ~3-4.5% total cost saving or less due to UE implementation and possibly dynamic buffer sharing  16->4 HARQ processes  Source 3 [20]: 13.95% total cost saving  Source 5 [30]: 6% baseband cost saving |
| Restricted max TBS | Baseband:  LDPC decoding [1, 6, 17, 20, 30]  HARQ buffer [1, 6, 17, 20, 30]  UL processing block [1, 6, 17, 20, 30]  DL processing block [30] | Reducing Max TBS by 10-fold for both UL and DL:  Source 1 [1]: ~90% cost saving in LDPC decoding, HARQ buffer size and UL processing block.  Reducing Max TBS to 1/5 for both UL and DL:  Source 2 [17]: 10~15% total complexity gain but should not be double counted if BW is reduced.  Reducing Max TBS from 10000 bits in DL to 1000 bits and 5000 bits in UL to 1000 bits  Source 5 [30]: up to 16% in DL and 5% in UL total cost saving (based on 36.888)  Reducing maximum TBS by reducing BW from 100 MHz -> 5 MHz  Source 3 [20]: 22.8% total cost saving  Reducing maximum TBS by reducing BW from 100 MHz -> 20 MHz  Source 3 [20]: 19.2% total cost saving  150 Mbps DL -> 10 Mbps DL and 50 Mbps UL-> 5 Mbps UL  Source 4 [6]: 13% total cost saving |

### 7.6.3 Analysis of performance impacts

Contributions [1, 5, 6, 17, 30] analyze the performance impact if the reduced maximum number of MIMO layers, restricted maximum modulation order, restricted maximum TB sizes or reduced maximum number of HARQ processes is introduced for RedCap UEs. The findings are listed below.

***Reduced maximum number of MIMO layers***

* Data rates:
  + P1.1: Reduced maximum data rates [1, 5]
* Coverage:
  + P1.2: No coverage impacts [17, 30]
* Cell spectrum efficiency:
  + P1.3: Reduced cell spectrum efficiency [17]
* Power consumption:
  + P1.4: Power consumption of higher data rate seems larger than that of lower data rate [20]

***Restricted maximum modulation order***

* Data rates:
  + P2.1: Reduced maximum data rates [1, 5]
* Coverage:
  + P2.2: No coverage impacts [17, 30]
* Cell spectrum efficiency:
  + P2.3: Reduced cell spectrum efficiency [6, 17]
* Power consumption:
  + P2.4: Power consumption of higher data rate seems larger than that of lower data rate [20]
  + P2.5: Small reduction in power consumption [6]

***Restricted maximum TB sizes***

* Data rates:
  + P3.1: Reduced maximum data rates [1, 17]
* Coverage:
  + P3.2: Reduced / limited impact on coverage due to loss of channel coding gain [6, 17]
  + P3.3: No coverage impacts [30]
* Cell spectrum efficiency:
  + P3.4: Reduced / limited impact on spectral efficiency due to loss of channel coding gain [6, 17]
* Power consumption:
  + P3.5: Increase slightly for a UE with good SNR due to longer Tx/Rx times [6]

***Reduced maximum number of HARQ processes***

* Data rates:
  + P4.1: Sustainable data rates may not be achieved [1]
* Coverage:
  + P4.2: No coverage impacts [30]

**Q 7.6.3-1: Does the list (P1.1, P1.2, …, P4.2) above capture the most important performance impacts that need to be considered for reduced maximum number of MIMO layers, restricted maximum modulation orders, restricted TB sizes and reduced maximum number of HARQ processes? If not, what other aspects need to be added?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | TBD after agree what to study |
| Ericsson | TBD, depending on the exact scope |
| Sierra Wireless | Yes |
| ZTE,Sanechips | Yes |
| Panasonic | Yes |
| vivo | ***Reduced maximum number of MIMO layers :*** fine with all points  ***Restricted maximum modulation order:*** fine with all points  ***Restricted maximum TB sizes:*** fine with all points  ***Reduced maximum number of HARQ processes:*** P4.1 is conditional and related to HARQ turn-around time, P4.2 is fine |
| Samsung | To align whether to add coverage analysis with other features.  Some of the above list needs to be further discussed. |
| OPPO | ***Yes*** |
| Huawei, HiSilicon | Y |
| Sequans | Yes |
| Lenovo, Motorola Mobility | TBD |
| Intel | FFS |
| Nokia, NSB | Y |
| Qualcomm | TBD |

**Q 7.4.3-2: Which of the identified performance impacts in the list above (P1.1, P1.2, …, P4.2) are the most critical ones to be captured in TR 38.875?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | P1.1, P2.2 |
| FUTUREWEI | TBD after agree what to study |
| Ericsson | TBD, depending on the exact scope |
| Sierra Wireless | P1.1, P1.2, P1.3, P2.1, P2.2, P2.3, P3.1, P3.5, |
| Spreadtrum | TBD. |
| ZTE,Sanechips | P1.x and P2.x |
| Panasonic | P1.1, P1.3, P2.1, P2.3 |
| vivo | The same comment as above |
| Example | P1.1, P2.2 |
| OPPO | P1/P2/P3 |
| Huawei, HiSilicon | P1.1, P1.3;  P2.1, P2.3;  P4.1 |
| Sequans | FFS |
| Lenovo, Motorola Mobility | TBD |
| Intel | FFS |
| Nokia, NSB | TBD |
| Qualcomm | TBD |

### 7.6.4 Analysis of coexistence with legacy UEs

Five contributions [1, 6, 17, 20, 30] provide coexistence analysis on restricting the maximum modulation orders, the maximum number of MIMO layers, the maximum modulation orders, the TB sizes or reducing the maximum number of HARQ process. Two contributions [1, 17] explicitly indicate there will be no coexistence issues if the four techniques are employed for RedCap UEs. Hence, the identified issues are:

* C1: No identified issues

**Q 7.6.4-1: Does the list above (C1) capture the most important coexistence impacts that need to be considered for reduced maximum number of MIMO layers, restricted maximum modulation orders, restricted TB sizes and reduced maximum number of HARQ processes? If not, what other aspects need to be added?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | TBD after agree what to study |
| Ericsson | TBD, depending on the exact scope |
| Sierra Wireless | Yes |
| ZTE,Sanechips | Yes |
| Panasonic | Yes |
| vivo | OK |
| Samsung | Maybe not.  Further discussion on whether restricted TB will impact on Msg 4 and potentially TB for SIB/paging, might need to further discussed. It will depends on the max TB size. |
| OPPO | yes |
| CMCC | Yes |
| Huawei, HiSilicon | The reduced data rate and SE will effectively result in reduced total available resources for legacy UEs, due to reduction of max MIMO layers, modulation orders. |
| Sequans | Yes |
| Lenovo, Motorola Mobility | TBD |
| Intel | FFS |
| Nokia, NSB | Y |
| Qualcomm | TBD |

**Q 7.6.4-2: Shall the identified coexistence impacts in the list above (C1) be captured in TR 38.875?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FUTUREWEI | TBD after agree what to study |
| Ericsson | TBD, depending on the exact scope |
| Sierra Wireless | Yes |
| ZTE,Sanechips | Yes |
| Panasonic | Yes |
| vivo | OK |
| Samsung | See the common above |
| OPPO | Yes |
| CMCC | Yes |
| Huawei, HiSilicon | A bit early to conclude. |
| Sequans | FFS |
| Lenovo, Motorola Mobility | TBD |
| Intel | FFS |
| Nokia, NSB | Y |
| Qualcomm | TBD |

### 7.6.5 Analysis of specification impacts

Contributions [1, 6, 17, 20, 30] indicate that there may be limited specification impacts. Identified specification impacts are listed below:

* S1: DCI optimization [6]
  + due to restricted maximum modulation order
* S2: optimized CQI table
  + due to restricted maximum modulation order [1, 5]
  + due to restricted maximum TBS [1]
* S3: optimized MCS table
  + due to restricted maximum modulation order [1, 5]
  + due to restricted maximum TBS [1]
* S4: UE capability indication to notify the network of UE’s reduced capabilities
  + due to reduced maximum number of HARQ processes, restricted maximum modulation order, maximum number of MIMO layers, TB sizes [1, 20]
* S6: RAN4 demodulation requirements
  + due to reduced maximum number of HARQ processes [1]

One contribution [30] further indicates that restricting the maximum TBS and reducing the maximum number of HARQ processes have least or smaller specification impact compared to other techniques.

**Q 7.6.5-1: Does the list above (S1, S2, …, S6) capture the most important specifications impacts that need to be considered for reduced maximum number of MIMO layers, restricted maximum modulation orders, restricted TB sizes and reduced maximum number of HARQ processes? If not, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| FUTUREWEI | N | TBD after agree what to study. Likely none of these included, as L1 changes should be minimized, and reuse of existing DCI/CQI/MCS etc is possible. |
| Ericsson | N | TBD, depending on the exact scope |
| Sierra Wireless | Y |  |
| Spreadtrum | N | Plus reducing the number of PRBs allocated for PDSCH/PUSCH |
| ZTE,Sanechips | N | Seems there are impacts missing , for example RAN4 CSI performance requirements due to optimized CQI table |
| vivo |  | The list is fine. S1/2/3 are optimizations thus not critical. S4 and S6 should be addressed by the spec. |
| Samsung |  | Some of the above list needs to be further discussed. |
| OPPO | Y |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y | TBD.  Overall, for capturing specification impact, our suggestion is to clarify the scope and strictly follow that. Once one impact is confirmed then we capture that. Debate on a conclusion like “no other spec impact than the above identified” at this stage is not necessary. |
| Sequans | FFS |  |
| Lenovo, Motorola Mobility | N | TBD, with low priority. |
| Intel |  | TBD, given currently unclear scope |
| Nokia, NSB | TBD |  |
| Qualcomm | N | TBD |

**Q 7.6.5-2: Which of the identified specification impacts in the list above (S1, S2, …, S6) are the most critical ones to be captured in TR 38.875?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Example | S1, S2 |
| FUTUREWEI | TBD after agree what to study. Likely none. |
| Ericsson | TBD, depending on the exact scope |
| Sierra Wireless | S4 |
| Spreadtrum | S4. |
| ZTE,Sanechips | S1,S2,S3, S4, S6 |
| vivo | S4, S6 |
| OPPO | S1/3/4/6 |
| CMCC | S2,S3,S4 |
| Huawei, HiSilicon | None at this moment. |
| Sequans | FFS |
| Lenovo, Motorola Mobility | TBD |
| Intel | TBD, given currently unclear scope |
| Nokia, NSB | TBD |
| Qualcomm | At least S4 |

# References

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| --- | --- | --- | --- |
| [1] | [R1-2005234](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005234.zip) | Potential UE complexity reduction features for RedCap | Ericsson |
| [2] | [R1-2005269](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005269.zip) | Potential UE complexity reduction features | Huawei, HiSilicon |
| [3] | [R1-2005277](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005277.zip) | Complexity reduction features for RedCap UEs | FUTUREWEI |
| [4] | [R1-2005383](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005383.zip) | Discussion on complexity reduction for Reduced Capability NR devices | vivo, Guangdong Genius |
| [5] | [R1-2005474](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005474.zip) | Potential UE complexity reduction features | ZTE |
| [6] | [R1-2005525](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005525.zip) | UE complexity reduction features | Nokia, Nokia Shanghai Bell |
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| [8] | [R1-2005637](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005637.zip) | On complexity reduction features for NR RedCap UEs | MediaTek Inc. |
| [9] | [R1-2005714](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005714.zip) | Discussion on potential UE complexity reduction features | CATT |
| [10] | [R1-2005770](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005770.zip) | Potential UE complexity reduction features | TCL Communication Ltd. |
| [11] | [R1-2005830](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005830.zip) | On UE complexity reduction features for RedCap | Lenovo, Motorola Mobility |
| [12] | [R1-2005880](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005880.zip) | On complexity reduction for RedCap UEs | Intel Corporation |
| [13] | [R1-2005937](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005937.zip) | Reduced Capability UE Complexity Reduction Features | Sierra Wireless, S.A. |
| [14] | [R1-2005959](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005959.zip) | Rel-16 UE power saving features for RedCap | NEC |
| [15] | [R1-2005968](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005968.zip) | Discussion on the complexity reduction for reduced capability device | Beijing Xiaomi Software Tech |
| [16] | [R1-2006036](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006036.zip) | Discussion on UE complexity reduction | OPPO |
| [17] | [R1-2006152](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006152.zip) | UE complexity reduction | Samsung |
| [18] | [R1-2006196](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006196.zip) | Discussion on potential UE complexity reduction features | Panasonic Corporation |
| [19] | [R1-2006217](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006217.zip) | Discussion on potential UE complexity reduction features | CMCC |
| [20] | [R1-2006272](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006272.zip) | Discussion on potential UE complexity reduction features | Spreadtrum Communications |
| [21] | [R1-2006306](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006306.zip) | Discussion on potential UE complexity reduction features | LG Electronics |
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| [23] | [R1-2006538](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006538.zip) | Complexity reduction features for reduced capability NR devices | InterDigital, Inc. |
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| [30] | [R1-2006988](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006988.zip) | UE Complexity Reduction Features for RedCap | Apple |
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| [32] | [R1-2006155](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2006155.zip) | Framework and Principles for Reduced Capability | Samsung |
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| [35] | [R1-2005960](http://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2005960.zip) | CBW for RedCap | NEC |

1. **depends on cost breakdown for each baseband part** [↑](#footnote-ref-2)
2. **depends on cost split between RF and baseband parts** [↑](#footnote-ref-3)