3GPP TSG-RAN WG1 Meeting #104-e Tdoc R1-21xxxxx

e-Meeting, January 25th – February 5th, 2021

**Agenda Item: 8.6.1**

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

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# Introduction

This document summarizes contributions [1] – [28] and captures the following email discussion for the RedCap WI [29].

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| --- |
| [104-e-NR-RedCap-01] Email discussion on UE complexity reduction – Johan (Ericsson)* 1st check point: Jan 28
* 2nd check point: Feb 2
* 3rd check point: Feb 4
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The issues in this document are tagged and color coded like this:

1. High Priority
2. Medium Priority

In this round of the discussion, please provide input to High Priority questions by Wednesday 27th January 16:00 UTC.

Follow the naming convention in this example:

* *RedCapFLS1-v000.docx*
* *RedCapFLS1-v001-CompanyA.docx*
* *RedCapFLS1-v002-CompanyA-CompanyB.docx*
* *RedCapFLS1-v003-CompanyB-CompanyC.docx*

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

* Assume CompanyC wants to update *RedCapFLS1-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapFLS1-v003-CompanyB-CompanyC.checkout*
* CompanyC then has 30 minutes to upload *RedCapFLS1-v003-CompanyB-CompanyC.docx*
* If no update is uploaded in 30 minutes, other companies can ignore the checkout file.
* Note that the file timestamps on the server are in UTC time.

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

# Reduced maximum UE bandwidths

According to Rel-15/16 NR specifications, a UE is required to support 100 MHz in FR1 and 200 MHz in FR2.

The WID [29] has the following objective on reduced maximum UE bandwidths:

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| * Reduced maximum UE bandwidth:
	+ Maximum bandwidth of an FR1 RedCap UE during and after initial access of 20 MHz is supported. The possibility of, and any associated conditions for, optional support of a wider bandwidth up to 40 MHz after initial access for this case will be further discussed at RAN#91e.
	+ Maximum bandwidth of an FR2 RedCap UE during and after initial access is 100 MHz
 |

## SSB and CORESET#0

Several contributions [1, 4, 19, 22] mention that, in the DL, since the maximum RedCap UE bandwidth exceeds the CORESET#0 bandwidth in both FR1 and FR2, SSB and CORESET#0 can be shared between RedCap UEs and legacy UEs. Also, contribution [19] states that during the initial access Msg2 and Msg4 are required to be transmitted within the CORESET#0 bandwidth, there is no problem in the reception of Msg2 and Msg4 in both FR1 and FR2. On the other hand, contribution [6] suggests that the network can offload the transmissions for RedCap UEs to a separated CORESET#0/initial BWP, which is FDM multiplexed with the normal UEs.

**High Priority Question 2.1-1: Should RedCap and legacy UEs be able to share the same SSB and CORESET#0?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | Based on the WID of R17 RedCap devices, the max UE BW of RedCap devices is 20 MHz for FR1 and 100 MHz for FR2. As a result, there is no problem for a RedCap device to decode the SSB/CORESET0 targeting non-RedCap devices.  |
| DOCOMO | Y |  |
| Ericsson | Y | RedCap UE bandwidth is large enough to support all the SSB configurations and all the CORESET#0 configurations, in FR1 and FR2 bands. |
| Nokia, NSB | Y |  |
| TCL | Y |  |
| ZTE | Y | RedCap UEs and legacy UEs can share the same SSB/CORESET0. |
| CMCC | Y | SSB and CORESET#0 carry common information for the cell, so there is no capacity issue, and based on the agreed maximum RedCap bandwidth, the RedCap devices have no problems to receive SSB and CORESET#0. Therefore, it is better to share the same SSB and CORESET#0.  |

A few contributions [1, 12, 19, 27] discuss the impact of bandwidth reduction on the SSB and CORESET#0 acquisition time. In FR2, SSB and CORESET#0 can be frequency domain multiplexed for multiplexing patterns 2 and 3. In some specific cases, the total bandwidth can span more than 100 MHz. This requires frequency retuning and sequential acquisition of SSB and CORESET#0 which may result in an additional latency. Nevertheless, such additional latency is acceptable for RedCap use cases thus no enhancement is needed for SSB/CORESET#0 acquisition [1, 12]. In contribution [19], it is mentioned that implementation-based solution is sufficient to handle the problematic configurations where the SSB and CORESET#0 span more than 100 MHz. Also, one contribution [27] discusses an approach for proper frequency retuning for SSB and CORESET#0 acquisition.

**Medium Priority Question 2.1-2: Should RAN1 consider acquisition time improvements for FR2 RedCap UEs with SSB and CORESET#0 multiplexing patterns 2 and 3?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Ericsson | N | In most of the SSB/CORESET#0 configurations, it is still possible to simultaneously acquire SSB and CORESET#0. There are only special SSB/CORESET#0 configurations for which the total SSB/CORESET#0 bandwidth exceeds the UE bandwidth.First, acquisition time is not a critical consideration for RedCap use cases, so it is perfectly fine for a RedCap UE to acquire SSB and CORESET#0 in a sequential manner.Furthermore, UE implementation-based solutions may be used for improving the acquisition time, e.g., the UE may be able to skip some part of the SSB to receive SSB and CORESET#0 simultaneously, but with some loss of performance. |
| Nokia, NSB  | N | It is not necessary to optimize acquisition time for these multiplexing patterns. |
|  |  |  |

## Initial BWPs

In principle, the initial BWP may be configured to span up to the entire carrier bandwidth. In the coexistence of RedCap UEs with legacy NR UEs, two general directions can be considered: 1) shared initial BWPs, and 2) separate initial BWPs.

Several contributions [1, 4, 18, 20, 24, 26] support having shared initial BWPs for RedCap and legacy UEs while other contributions [3, 6, 7, 8, 11, 23, 24] mention that having separate initial BWPs can be desirable or more feasible. In case of shared initial BWPs that exceed the UE BW, there might be a couple of issues that need to be discussed.

**High Priority Question 2.2-1: Should RedCap and legacy UEs be able to share the same initial DL BWP?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | It depends | It depends on the BW of initial DL BWP configured for legacy (non-RedCap) UE:1. If the BW of initial DL BWP for legacy UEs is no wider than the max UE BW of RedCap devices for initial access (e.g. 20 MHz for FR1 and 100 MHz for FR2), the initial DL BWP should be shared between legacy UE and RedCap UE
2. If the BW of initial DL BWP for legacy UEs is wider than the max UE BW of RedCap devices for initial access (e.g. 20 MHz for FR1 and 100 MHz for FR2), the initial DL BWP for RedCap devices needs to be separately configured, subject to the condition of sharing SSB/CORESET0/SIB1 with legacy UE.
	* In this case, the initial DL BWP configuration for RedCap UE can be provided in the SIB1 (shared with legacy UE), or based on rules defined in spec. More details can be found in our contribution [22].
 |
| DOCOMO | Y | We think it’s better that both 1) shared initial BWPs, and 2) separate initial BWPs are configurable for flexible operation |
| Ericsson | Y | There are two options for configuring an initial BWP (See subclause B2 in TS38.331):− Option 1: Configure the initial BWP (BWP #0) with cell-specific parameters only;− Option 2: Configure the BWP #0 with both cell-specific and UE-specific parameters.Currently some networks use Option 1 and some networks use Option 2. In our view, it is very important that an MNO can keep the option that it has been using, if it enables the support for RedCap UEs. One motivation for an operator to have chosen Option 2 is that the network can set up a fully operational connection with a UE by only configuring DL/UL BWP #0, without having to configure additional BWPs. With Option 2, a most common initial BWP configuration is to configure the initial BWP to use the entire carrier bandwidth, e.g. 100 MHz in FR1. Thus, in our view, it is important for the specifications to support a RedCap UE to operate in an initial BWP configured with a larger bandwidth than the UE bandwidth.For Option 1, the bandwidth of the initial BWP will be within the RedCap UE bandwidth. Thus, it makes sense for RedCap and legacy UEs to be able to share the same initial DL BWP. |
| Nokia, NSB | Y | In our view, we don’t see a strong motivation to configure initial DL BWP that is wider than the RedCap UE bandwidth. Doing so would require substantial specification work – either to accommodate RedCap UE in wider BWP or to configure a different initial DL BWP for RedCap UE.Our preference is that the initial DL BWP should be configured to be within the RedCap UE bandwidth. Therefore, RedCap and legacy UEs can share the same initial DL BWP. |
| TCL | Y |  |
| ZTE |  | Dedicated DL initial BWP should be configured for RedCap UEs if the size of initial DL BWP for legacy UEs is wider than the max UE bandwidth of RedCap UEs. If the size of initial DL BWP for legacy UEs is no wider than the max UE bandwidth of RedCap UEs, RedCap UEs and legacy UEs can share the same initial DL BWP. For offloading purpose, dedicated DL initial BWP can be configured for RedCap UEs. |
| CMCC | Partially Y | When there is no coexistence issue, and the traffic load is low in the initial BWP, RedCap devices can share the same initial UL BWP. Otherwise, the network should have the flexibility to configure separate initial BWP for RedCap devices. Therefore, it depends on the gNB configuration. |

In general, the shared BWP may or may not exceed the RedCap UE bandwidth. For a shared initial UL BWP exceeding the UE bandwidth, the potential issues are related to transmissions of PRACH preambles, Msg3 on PUSCH, HARQ feedback of Msg4 on PUCCH [1, 4, 14, 16, 18, 19, 22].

**High Priority Question 2.2-2: Should RedCap and legacy UEs be able to share the same initial UL BWP?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | It depends | It depends on the BW of initial UL BWP configured for legacy (non-RedCap) UE:1. If the BW of initial UL BWP for legacy UEs is no wider than the max UE BW of RedCap devices for initial access (e.g. 20 MHz for FR1 and 100 MHz for FR2), the initial UL BWP should be shared between legacy UE and RedCap UE
2. If the BW of initial UL BWP for legacy UEs is wider than the max UE BW of RedCap devices for initial access (e.g. 20 MHz for FR1 and 100 MHz for FR2), the initial UL BWP for RedCap devices needs to be separately configured.
 |
| DOCOMO | Y | We think it’s better that both 1) shared initial BWPs, and 2) separate initial BWPs are configurable for flexible operation |
| Ericsson | Y | Our response to Question 2.2-1 is applicable for both UL and DL initial BWPs (i.e., BWP #0).  |
| Nokia, NSB | Y | Same view as our response to DL BWP Question 2.2-1. |
| TCL | Y |  |
| ZTE | Y | Dedicated UL initial BWP should be configured for RedCap UEs if the size of initial UL BWP for legacy UEs is wider than the max UE bandwidth of RedCap UEs. If the size of initial UL BWP for legacy UEs is no wider than the max UE bandwidth of RedCap UEs, RedCap UEs and legacy UEs can share the same initial UL BWP. Dedicated UL initial BWP can be configured for RedCap UEs for RedCap UE identification. |
| CMCC | Partially Y | When there is no coexistence issue, and the traffic load is low in the initial BWP, RedCap devices can share the same initial UL BWP. Otherwise, the network should have the flexibility to configure separate initial BWP for RedCap devices. Therefore, it depends on the gNB configuration. |

**RACH occasions outside the UE bandwidth**

RACH occasions can be frequency multiplexed. For specific configurations with 8 RACH occasions for 30 or 120 kHz SCS, the total frequency span of 8 RACH occasions can be greater than the UE bandwidth. Consequently, a RACH occasion associated with the best SSB can fall outside the UE bandwidth. Some contributions [1, 14, 16, 18, 19, 22] propose solutions to address this issue, which include:

* Proper RF-retuning for RedCap [1, 16, 19]
* Dedicated PRACH resources configured in SIB1 [22]
* gNB to configure the number of SSB indexes associated with one RO to be larger than one [16]
* Apply restrictions on the PRACH configurations for RedCap (e.g., network should not configure, and UE does not expect such configurations) [14, 16]

Moreover, one contribution [22] proposes to support early indication of RedCap by configuring dedicated PRACH resources for RedCap UE, wherein the PRACH can be used for Msg1 transmission of 4-step RACH, or MsgA preamble transmission of 2-step RACH.

**Medium Priority Question 2.2-3: What, if any, techniques should be considered to avoid the case where a RACH occasion associated with the best SSB falls outside the RedCap UE bandwidth?**

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| --- | --- |
| **Company** | **Comments** |
| Qualcomm | By configuration, gNB needs to ensure: *within a SSB-RO association pattern period and within the BW for initial UL BWP of RedCap UE, the PRACH resources available for RedCap UE can associate with all transmitted SSB beams. Besides, a threshold for SSB-based RSRP measurements can be configured for RedCap UE to identify the suitable/best SSB beam(s).* |
| Ericsson | We prefer RF-retuning. After transmission of PRACH by RF-retuning, the UE may have to retune to another center frequency in order to monitor for RAR. Since the RAR window may start one symbol after the last symbol of the PRACH occasion, the RF-retuning time needs to be considered when the network transmits RAR to the RedCap UE. However, this issue can be resolved if there is early RedCap indication in Msg1 available in this scenario.Regarding the approach of using “dedicated PRACH resources configured in SIB1”, our concern is that this may result in multiple initial UL BWPs. Having multiple initial UL BWPs will have the negative consequence of PUSCH resource fragmentation for non-RedCap UEs due to PUCCH FH at the edge of the BWP.Regarding the approach of allowing “gNB to configure the number of SSB indexes associated with one RO to be larger than one”, our concern is that this may have a negative impact on non-RedCap UEs. |
| Nokia, NSB | We prefer to apply restrictions on the PRACH configurations for RedCap (e.g., network should not configure, and UE does not expect such configurations) |
| CMCC | If the network has prepared to serve both RedCap and non-RedCap devices, it can handle this. For example, when current RACH configurations can not satisfy the maximum bandwidth requirement of RedCap devices, and change of the configuration will degrade performance of non-RedCap devices, the gNB can configure separate RACH resources, separate initial UL BWP for RedCap devices. Otherwise, it can change the RACH configurations to better serve RedCap devices. |

**PUCCH/PUSCH frequency hopping outside the UE bandwidth**

Another potential issue in a shared initial UL BWP is related to the frequency hopping for PUCCH (Msg4 HARQ feedback) and PUSCH (Msg3) during the initial access procedure. In these cases, frequency hopping can be configured and the associated PRBs are determined based in the initial UL BWP configuration, which may have a bandwidth larger than the maximum RedCap UE bandwidth. Similar to the RACH occasion issue, few contributions discuss potential solutions, which include:

* Proper RF-retuning for RedCap [1, 18, 19]
* Separate PUCCH configuration for Redcap (e.g., disabled, or different hopping) [19]

**Medium Priority Question 2.2-4: What, if any, techniques should be considered to avoid the case where a PUCCH (for Msg4 HARQ) or PUSCH (for Msg3) falls outside the RedCap UE bandwidth due to frequency hopping?**

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| **Company** | **Comments** |
| Ericsson | We prefer RF-retuning. Configuring separate PUCCH resources results in fragmentation of PUSCH resources for non-RedCap UEs. The same concern applies to Connected Mode operation. |
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## BWP operation

Several contributions [1, 4, 8, 11, 18, 20, 22, 26] highlight different aspects related to the BWP operation for RedCap UEs after the initial access. These aspects include BWP switching mechanisms and narrow BWP operation for power saving and potentially SSB-based measurements [1, 4, 18, 22], BWP hopping for frequency diversity and interference mitigation [11, 22], operating in a wide BWP [19, 20], and fast BWP switching to dedicated BWP for offloading the initial BWP [26].

Meanwhile, some contributions [8, 11, 20] raise questions regarding the BWP switching time and RF retuning delay and propose to send an LS to RAN4.

One contribution [10] suggests that the support of multiple BWP could be optional for RedCap UE.

**Medium Priority Question 2.3-1: What, if any, BWP switching mechanisms are needed for RedCap UEs in addition to existing BWP switching mechanisms?**

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| --- | --- |
| **Company** | **Comments** |
| Ericsson | It is sufficient to support existing BWP switching mechanisms. |
| TCL | Redcap UEs switching to the dedicated BWP immediately after random access procedure may be considered to offload UEs from initial BWP. |
|  |   |

## Bandwidth after initial access

Several contributions [1, 2, 3, 5, 7, 9, 15, 16, 18, 19, 20, 21, 22, 26, 28] express views on whether a wider bandwidth than 20 MHz, up to 40 MHz, should be optionally supported after initial access. According to the WID, this case will be further discussed in RAN#91e.

## Other prioritized impacts of reduced maximum UE bandwidths

**Medium Priority Question 2.5-1: What, if any, other potential RAN1 specification impacts from reduced maximum UE bandwidths (beyond the impacts discussed in previous sections in this document) do you think should be prioritized in this meeting?**

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| --- | --- |
| **Company** | **Comments** |
| Ericsson | None |
|  |  |
|  |  |

# Reduced minimum number of Rx branches

The WID [29] has the following objective on reduced minimum number of Rx branches:

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| --- |
| * Reduced minimum number of Rx branches:
	+ For frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports, the minimum number of Rx branches supported by specification for a RedCap UE is 1. The specification also supports 2 Rx branches for a RedCap UE in these bands.
	+ For frequency bands where a legacy NR UE (other than 2-Rx vehicular UE) is required to be equipped with a minimum of 4 Rx antenna ports, the minimum number of Rx branches supported by specification for a RedCap UE will be decided at RAN#91e; hence no specific work for these frequency bands will be done before RAN#91e.
 |

Many contributions [1, 3, 4, 5, 6, 7, 11, 12, 16, 18, 19, 20, 21, 22, 23, 25, 28] express views on the minimum number of Rx branches for RedCap UEs operating in frequency bands where a legacy NR UE is required to be equipped with 4 Rx. According to WID, the related aspects to these frequency bands shall be discussed after RAN#91e.

Several contributions [1, 2, 3, 7, 8, 10, 11, 12, 13, 16] express views on RedCap UE type definition and early indication of UE type. This topic belongs more under agenda item 8.6.2 which will not be discussed in this meeting according to the agenda.

A few contributions [1, 2, 3, 4, 13] express views on coverage recovery solutions. According to the WID, the appropriate WI for handling of any potential coverage recovery aspects related to RedCap UEs devices will be considered at RAN#91e. Contribution [3] also suggests specifying a mechanism to handle antenna inefficiency. The WID currently does not include any explicit objective on antenna inefficiency.

Contribution [3] suggests that either the MCS table for NR normal coverage or the low spectral efficiency MCS table for PDSCH which does not have 256QAM entries is used for RedCap devices, or a new MCS table optimized for RedCap UEs is defined.

Regarding the specification impacts, some contributions [1, 5, 7] express that the impact on RAN1 specifications is limited, and some contributions [1, 3, 7, 10, 13] express that the impact on several aspects of RAN4 specifications should be evaluated (mainly related to RAN4 performance requirements, including demodulation performance, CSI reporting, RRM, cell handover or (re)selection, radio link management, beam management).

**High Priority Question 3-1: For FR1 and FR2 frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports, what RAN1 specification impacts (beyond possible early UE type identification and possible coverage recovery related functionality) do you expect from reduced minimum number of Rx branches for RedCap devices?**

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| **Company** | **Comments** |
| Qualcomm | We don’t expect significant impacts on RAN1 except for:1. early UE type indication discussed in Section 2.3 of this document
2. possible coverage recovery related functionality to compensate for reduced antenna efficiency
3. for FR2, UE antenna configuration (polarization/panels) report to the gNB
 |
| DOCOMO | We think some solution for reducing PDCCH blocking rate should be discussed in coexistence of RedCap and legacy UEs, as higher AL would be necessary for RedCap UEs due to reduced number of Rx antenna ports, which results in increased PDCCH blocking rate |
| Ericsson | None. |
| Nokia, NSB | None |
| TCL | We prefer to discuss PDCCH repetition, because coverage recovery is required for RedCap UEs due to the reduction in the number of Rx antenna ports. We also agree with the DOCOMO comment. |
| ZTE | None |
| CMCC | None. |

# Maximum number of DL MIMO layers

The WID [29] has the following objective on relaxed maximum number of DL MIMO layers:

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| --- |
| * Maximum number of DL MIMO layers:
	+ For a RedCap UE with 1 Rx branch, 1 DL MIMO layer is supported.
	+ For a RedCap UE with 2 Rx branches, 2 DL MIMO layers are supported.
 |

Several contributions [1, 2, 4, 7, 8, 13, 20] suggest that there is no particular need to characterize the maximum number of DL MIMO layers specifically, but this can instead relate to the number of Rx branches, discussed in the previous section. Two contributions suggest reusing/modifying the behavior related to existing per-band capability*maxNumberMIMO-LayersPDSCH* [10] or *maxMIMO-Layers* [8]. The FL suggests that detailed agreements related to this issue are deferred to a later stage of the work item when, for example, the characterization of a RedCap UE in terms of capabilities becomes clearer and has also been discussed in RAN2.

Some contributions discuss possible DCI impacts. Contributions [8, 5, 18] indicate that there may be a possibility to reduce the number of bits for antenna port indication when the maximum number of MIMO layers is reduced. Other contributions discuss implications on DCI in more general terms, as listed below in Section 7. This includes the proposal in one contribution [1] not to introduce minor optimizations of DCI sizes.

One contribution [1] suggests that notes can be added to the clarify UE behavior related to, e.g., PDSCH reception, CSI reporting and DCI.

**High Priority Question 4-1: What RAN1 specification impacts (beyond UE capability signalling) do you expect from reduced maximum number of DL MIMO layers for RedCap devices?**

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| --- | --- |
| **Company** | **Comments** |
| Qualcomm | We don’t expect significant impacts in RAN1, but clarification/simplification of UE procedures for RedCap devices can be considered as a result of MIMO layer reduction, such as DCI processing and CSI measurement/reporting. |
| DOCOMO | No critical specification impacts are seen so far |
| Ericsson | We foresee minor specification impacts (e.g., in the form of a short sentence or a note; details FFS, pending e.g. general RedCap UE characterization/indication and discussion on number of RX branches) in TS 38.214, and more specifically in the section on physical downlink shared channel related procedures. |
| Nokia, NSB | None |
| TCL | None |
| ZTE | There may be some signaling optimization including UE capability signaling, higher layer parameter and DCI indication field. |
| CMCC | None. |

# Relaxed maximum modulation order

The WID [29] has the following objective on relaxed maximum modulation order:

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| * Relaxed maximum modulation order:
	+ Support of 256QAM in DL is optional (instead of mandatory) for an FR1 RedCap UE.
	+ No other relaxations of maximum modulation order are specified for a RedCap UE.
 |

Several contributions express views on the specification impacts due to relaxed maximum DL modulation order in FR1. Most contributions [1, 2, 5, 7, 8, 20, 25] observe that no introduction of new or optimization of existing MCS tables, CQI tables and/or DCI are necessary for RedCap devices.

However, in contribution [2], it is proposed that the lower spectral efficiency table should be the default table when a UE does not support 256QAM and has on receive antenna. In contribution [5], it is suggested that the network can determine which MCS table and CQI table to use based on UE capability.

A few contributions [1, 7, 8, 25] indicate the UE capability signaling would be the main impact. Contributions [1, 8] further note that the existing parameter “*pdsch-256QAM-FR1*” may be re-used for RedCap devices.

In contribution [7], it is further noted that UE behavior is not defined when there is scheduling error for using 256QAM.

**High Priority Question 5-1: What RAN1 specification impacts (beyond UE capability signalling) do you expect from relaxed maximum DL modulation order in FR1 for RedCap devices?**

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| --- | --- |
| **Company** | **Comments** |
| Qualcomm | For relaxed max DL modulation order, we don’t expect significant impacts in FR1, except for supporting low-SE MCS table of NR R15 during initial access of RedCap devices. |
| DOCOMO | No critical specification impacts are seen so far |
| Ericsson | None |
| Nokia, NSB | None |
| TCL | None |
| ZTE | None |
| CMCC | None. |

# Duplex operation

The WID [29] has the following objective on relaxed maximum modulation order:

|  |
| --- |
| * Duplex operation:
	+ HD-FDD type A with the minimum specification impact (Note that FD-FDD and TDD are also supported.)
 |

From the submitted contributions, two main specification impacts have been identified, namely, the DL-to-UL and UL-to-DL switching time and the UE behaviour in handling DL/UL collision.

On the switching time, several contributions [1, 2, 5, 6, 8, 11, 13, 19, 20, 22, 23, 24, 25] mention the existing definition and description of UEs not capable of full duplex communication in TS 38.211, also shown below. In short, the switching time $N\_{Rx-Tx}T\_{c}$ and $N\_{Tx-Rx}T\_{c}$ defined for UE not capable of full duplex in FR1 is equal to 13.02$ μs$, which amounts to less than 1 OFDM symbol for 15/30/60 kHz SCS.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC, simultaneousRxTxInterBandCA or simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to transmit in the uplink in one cell within the group of cells earlier than $N\_{Rx-Tx}T\_{c}$ after the end of the last received downlink symbol in the same or different cell within the group of cells where $N\_{Rx-Tx}$ is given by Table 4.3.2-3. A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC*, *simultaneousRxTxInterBandCA* *or simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to receive in the downlink in one cell within the group of cells earlier than $N\_{Tx-Rx}T\_{c}$ after the end of the last transmitted uplink symbol in the same or different cell within the group of cells where $N\_{Tx-Rx}$ is given by Table 4.3.2-3. A UE not capable of full-duplex communication is not expected to transmit in the uplink earlier than $N\_{Rx-Tx}T\_{c}$ after the end of the last received downlink symbol in the same cell where $N\_{Rx-Tx}$ is given by Table 4.3.2-3. A UE not capable of full-duplex communication is not expected to receive in the downlink earlier than $N\_{Tx-Rx}T\_{c}$ after the end of the last transmitted uplink symbol in the same cell where $N\_{Tx-Rx}$ is given by Table 4.3.2-3.Table 4.3.2-3: Transition time $N\_{Rx-Tx}$ and $N\_{Tx-Rx}$

|  |  |  |
| --- | --- | --- |
| **Transition time** | **FR1** | **FR2** |
| $$N\_{Tx-Rx}$$ | 25600 | 13792 |
| $$N\_{Rx-Tx}$$ | 25600 | 13792 |

 |

Some contributions [1, 6, 8, 11, 13, 22] express their views that the existing switching times above should be sufficient for HD-FDD Type-A UE, e.g., it is argued that HD-FDD Type-A UE can be assumed to have separate local oscillators for DL and UL and thus does not require much time to retune its frequency when switching the direction [1, 11], and that it is sufficient to accommodate the general ON-OFF time mask of 10 $μs$ as defined by RAN 4 [22].

Different options for the switching time for HD-FDD Type-A UE can be summarized as follows:

* **Option 1:** Either reuse existing switching times for UE not capable of full duplex in TS 38.211, or define new symbol-level switching times, based on RAN4 feedback.
* **Option 2:** Reuse LTE HD-FDD Type-A approach.

**High Priority Question 6-1: Regarding switching times for HD-FDD Type-A RedCap UEs, is it enough to consider the two options listed above, or are there other options that should be considered?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | Option 1 is preferred. It is necessary to send an LS to RAN4 for confirmation. |
| DOCOMO | Y | We prefer Option 1 if there is no critical issue |
| Ericsson | Y |  |
| Nokia, NSB | Y | We prefer Option 2 |
| TCL | Y | Option 1 is preferred. |
| ZTE | Y | Option 1can be the starting point. Final decision is made by RAN4 |
| CMCC | Y |  |

Regarding how HD-FDD Type-A UE handles DL/UL collision, several contributions have expressed their views. Contributions [1, 7, 8, 11, 12, 18, 19, 23] mentioned that in general, collision may be avoided by the scheduler. However, several contributions [1, 2, 6, 7, 13, 19, 20] also noted that DL/UL collision may not be avoidable in some scenarios and would be handled by UE.

Several contributions have expressed their views on how UE should handle potential collision cases. For example, contributions [1, 2, 5] proposed to reuse the same definition for UE behavior as defined for UE not capable of full duplex communication in TS 38.211. Contributions [6, 8, 20, 19, 25] proposed to reuse the existing rules defined for TDD in TS 38.213 (Section 11.1). Other mentioned solutions include using LTE/LTE-M approach [3, 12, 18] or having some signal/channel-specific prioritization rule such as PUCCH, PUSCH, aperiodic SRS > PDCCH, P/SP-CSI-RS > P/SP-SRS [21].

It was also mentioned by some contributions [1, 6, 7, 14, 16] that special attention may be needed when it comes to collision between dynamic and configured transmission/reception. For example, contributions [1, 6, 7, 14, 19, 20] mentioned that dynamic scheduling should be prioritized over semi-static configured transmission/reception.

As a starting point, it would be good to identify relevant DL/UL collision cases now and discuss potential solutions at a later stage. In general, there can be different collision scenarios between DL reception and UL transmission which may be categorized as follows:

* **Case 1:** Dynamically scheduled DL reception vs. semi-statically configured UL transmission
	+ e.g., dynamic PDSCH or CSI-RS collides with configured SRS, PUCCH, or CG PUSCH
* **Case 2:** Semi-statically configured DL reception vs. dynamically scheduled UL transmission
	+ e.g., PDCCH or SPS PDSCH collides with dynamic PUSCH or PUCCH
* **Case 3:** Semi-statically configured DL reception vs. semi-statically configured UL transmission
* **Case 4:** Dynamically scheduled DL reception vs. dynamic scheduled UL transmission
* **Case 5:** Configured SSB vs. UL transmission
	+ e.g., PUSCH, PUCCH, PRACH, SRS

**Medium Priority Question 6-2: Is the list of DL/UL collision cases above complete in your view? If not, what other collision cases should be considered for RedCap UE?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Ericsson | Y |  |
| TCL | Y | A potential collision may happen when BWP switch and HD-FDD D-U switch performed successively but the time gap is not long enough to complete the previous switch. |
|  |  |  |

Regarding UE capability reporting on HD-FDD Type-A, some contributions have expressed their views on the preferred options, e.g., after initial access [4], during Msg1 [2], and after Msg3 [24]. In addition, contribution [21] proposed to treat HD-FDD as a default operation for RedCap UEs, while FD-FDD can be reported as part of UE capability. This topic belongs more under agenda item 8.6.2 which will not be discussed in this meeting according to the agenda.

In addition to the switching time and DL/UL collision handling, other related discussions and proposals are provided for HD-FDD Type A. For example, contributions [9, 18, 19, 22] propose to support semi-static TDD-like slot configuration for HD-FDD Type-A UE, contributions [1, 7] propose that HARQ-ACK bundling is not considered for HD-FDD, and contributions [4, 24] note that no specification impact in initial access/random access procedure is expected from HD-FDD Type-A UE.

**High Priority Question 6-3: Do you expect other RAN1 specification impacts from HD-FDD Type-A for RedCap UEs beyond specifying switching times and collision handling (and UE capability signalling)?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | We think it is necessary to discuss the semi-static, TDD-like slot format configuration (DL, flexible and UL) for RedCap UE, which have the following benefits:1. simplifying UE’s procedures for directional collision handling
2. reducing UE’s complexity and power consumption in Type-A HD-FDD operation
3. minimizing the spec impacts on R17 NR by re-using the solutions available in NR TDD
 |
| DOCOMO | N | No critical specification impacts are seen so far |
| Ericsson | N | Regarding using semi-static TDD-like slot configuration for HD-FDD Type-A UE, our concern is that such an approach would be more restrictive as UE transmission and reception have to follow the configured pattern. For HD-FDD, it is more flexible that transmission and reception can happen at any time. The only constraint is that it does not happen at the same time. Note that one of the motivations for semi-static TDD configurations is to avoid, e.g., UL-to-DL interference. Such an interference problem does not apply in FDD bands. |
| Nokia, NSB | N | We do not support the use of TDD-like slot configuration for HD-FDD. Such approach introduces unnecessary complexity and restricts gNB scheduling flexibility. In addition, to fully utilize all slots, different groups of UEs would have to be configured with different TDD configurations, which significantly increase implementation complexity. |
| TCL | Y | The TDD-like slot format configuration should be discussed. We share similar views as Qualcomm |
| ZTE | N | Semi-static TDD-like slot format configuration can be regarded as a collision handling solution for further study. |
| CMCC | Y | UE specific TDD like configurations can reuse the current TDD collision rules. When more flexibile slots are configured, more scheduling flexibility can also achieved. |

# Other aspects (for information)

**General aspects**

* [1] Avoid over-optimization for small benefits
* [1] In Rel-17, no need to introduce enhancements for high RedCap connection density scenarios
* [12] In principle, the network shall not restrict the configurations for the legacy UEs in order to guarantee the RedCap UE performance.
* [12] The performance degradation of legacy UEs due to the introduced vast RedCap UEs shall be reduced through e.g., access control, separate initial BWP for RedCap UEs, etc.
* [9] For RedCap UEs in FR1, there is no issue if the UEs do not achieve 150 Mbps.

**UE type definition**

A few contributions express views on UE type definition. Since UE type definition is still under study in RAN2, the FL suggests coming back to this discussion in a later RAN1 meeting.

* [10] Further study explicit definition of RedCap UE type(s) for RedCap UE identification between option 2 and 4
* [12]: If 1Rx branch is to be supported for FR1 TDD bands where a non-RedCap UE is required to be equipped with a minimum of 4 Rx branches, two RedCap UE types are to be defined, one with 1Rx and the other with 2Rx.
* [9] Economies of scale can drive the cost reduction for RedCap UE modems. Device types should be defined so as not to fragment the UE modem market. Evolution of a single market segment (e.g. wearables) may play an essential role in enabling other markets across all application scenarios through economies of scale for RedCap UE modems.

**System information transmissions**

A few contributions express views on system information transmission. Some of these contributions mention SIB1 specifically, whereas some contributions imply system information in general.

* [1] Avoid duplication of existing system information in new SIBs intended specifically for RedCap UEs
* [1] RedCap-specific information may be conveyed using the following options: 1) reusing the existing SIBs and defining new information elements in one of the existing SI blocks, or 2) introducing separate SIBs (i.e., new SI blocks for RedCap).
* [22] In FR1, NR RedCap UE and non-RedCap UE should share the same SIB1. Other SIBs for RedCap UE can be scheduled by SIB1 or transmitted on-demand within the initial BWP of RedCap UE.
* [19] In FR1, there is no impact on the reception of RMSI when the maximum UE bandwidth is 20MHz
* [7] Reuse Rel-15 SIB1 design for RedCap UEs.
* [4] Consider supporting configurability of using legacy SIB1 (possibly with RedCap specific IEs) or defining RedCap specific SIB1.
* [13] Consider supporting at least one of following alternatives:
	+ New field in SIB1 for RedCap UE
	+ New SIBX dedicated for RedCap UE

For SIB transmissions, the following approaches can be identified:

1. RedCap UEs and non-RedCap UEs share the same SIBs with SIBs extended to include RedCap specific IEs.
2. RedCap UEs and non-RedCap UEs share the same legacy SIBs. New SIBs are introduced to convey additional system information intended for RedCap UEs.
3. New SIBs are introduced to convey all system information needed for supporting RedCap UEs. RedCap UEs are not required to read the legacy SIBs.

**Initial access and paging**

Few contributions have expressed views on paging and other aspects related to the initial access procedure (which are not covered in the previous sections).

* [4] FFS configuration separation (of Redcap UEs and non-RedCap UEs) for paging or RAR specific to RedCap.
* [8] In Idle mode, dedicated paging occasions are considered for RedCap UEs.
* [20] Separated configuration for initial access and paging (for Redcap UEs from non-RedCap UEs) can be supported.

**Early indication**

Several contributions [3, 2, 7, 8, 10, 11, 13, 16, 18, 22] have expressed views on the need for early indication of RedCap UEs, e.g., in Msg1 and/or Msg3. With regards to Msg1 indication in specific, most of these contributions have highlighted the importance of Msg1 indication (e.g., for coverage recovery, when initial UL BWP greater than UE BW, etc.). Some of these contributions have also mentioned that the use of early indication can be configurable by the NW based on, for e.g., NW deployment, coverage recovery needs, configuration of initial UL BWP, etc.

**PDCCH search spaces and blocking**

A few contributions discuss techniques for reducing PDCCH blocking rate in coexistence of RedCap and legacy UEs. Some contributions have brought up solutions to solve the potential PDCCH blocking issue when the CORESET for RedCap UEs are shared/overlapped with that of non-RedCap UEs.

* [1] Strive to have CORESET designs that achieve efficient resource utilization.
* [4] FFS configuration separation for Paging or RAR specific to RedCap.
* [19] Consider extending the CORESET duration in time domain to enhance the CORESET capacity. Reuse the existing mapping design of REG bundle, CCE and PDCCH as much as possible.
* [20] Further study on allowing the DL resource outside of CORESET 0 for at least Type1-PDCCH CSS, Type 2-PDCCH CSS, and the scheduled PDSCH.
* [20] Support multi-PDSCHs/PUSCHs scheduling for PDCCH overhead reduction and PDCCH blocking rate reduction.
* [24] Consider whether to separate Type 1 CSS configuration for RedCap UEs in SIB1 to address some congestions.
* [25] Support compact DCI with potential further DCI reduction (than Rel-16 URLLC) for RedCap UEs.

**DCI definition**

A few contributions express general views on DCI design.

* [1] Reuse existing formats as much as possible avoiding minor optimizations aiming at saving a few bits
* [4] Consider supporting PDCCH enhancements from the perspective of PDCCH capacity and efficiency improvement, e.g. a compact DCI or a group-wise DCI.
* [24] Compared to the design of DCI formats 0\_1/1\_1, the design of DCI formats 0\_2/1\_2 can better adapt to characteristics of various RedCap use cases requirements, given the design of DCI formats 1\_2/0\_2 is of full flexibility with much more configurable DCI fields sizes.
* [25] Support compact DCI with potential further DCI size reduction for RedCap UEs.

The FL suggests down-prioritizing DCI format discussion until the open issues regarding minimum number of Rx branches and optional support of a wider bandwidth up to 40MHz after initial access in FR1 are further discussed at RAN#91e.

**TBS restriction**

* [13] TBS restriction should be considered for RedCap UE (to facilitate further complexity reduction).

**CSI reporting**

In addition, contribution [20] suggests CSI report enhancements for RedCap:

* [20] FFS CSI report for a wider BWP bandwidth, including PDCCH based CSI report (for RedCap UEs operating in a BWP larger than its UE bandwidth).
* [20] FFS support of SRS transmissions or CSI report for link adaptation outside active BWP (for RedCap UEs with UE-specific BWP no larger than its UE bandwidth).
* [20] Consider supporting SB CSI reporting for BWP size < 24 PRBs, at least for RedCap UEs:
	+ Support a SB size for BWP size < 24 PRBs, where the SB size can be fixed or configured
	+ When BWP size < 24 PRBs, the SB CSI reporting can be restricted to rank 1 only and a small number of CSI-RS ports (e.g. 2 or 4)

**Coverage related issues**

* [3] Consider specifying large PDCCH AL or PDCCH repetition for coverage recovery for Redcap UE with 1 Rx.
* [18] SUL can be considered as optional capability to meet high data rate requirement, SUL has additional benefit of improving uplink coverage
* [22] In FR1, SUL is not supported by NR RedCap UE. Coverage recovery on NUL can re-use at least the solutions provided by R-17 CE WI.

**Power saving solutions**

* [3] MIMO layer adaptation as specified in Rel-16 power saving shall be supported for a RedCap UE with 2 Rx branches.
* [10] RedCap UE with two Rx supports maximum one layer in DL if MIMO layer adaptation for power saving would be expected useful for the RedCap UE.
* [10] Semi-static adoption of power saving feature within active BWP.
* [18] BWP switching based on DCI, RRC and timer is supported to facilitate power saving.
* [22] For FR2, to save UE power and complexity, consider switching the UE to a narrow active BWP (NBWP) after initial access is complete. The switching may be network initiated/controlled, implicit, or UE initiated/requested.

# References

|  |  |  |  |
| --- | --- | --- | --- |
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| [2] | [R1-2100046](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100046.zip) | Complexity reduction features for RedCap UEs | FUTUREWEI |
| [3] | [R1-2101777](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101777.zip) | Discussion on UE complexity reduction(revision of [R1-2100165](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100165.zip)) | OPPO |
| [4] | [R1-2100230](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100230.zip) | Potential solutions for UE complexity reduction | Huawei, HiSilicon |
| [5] | [R1-2100389](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100389.zip) | Discussion on UE complexity reduction features | CATT |
| [6] | [R1-2100449](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100449.zip) | Discussion on UE Complexity reduction | Vivo, Guangdong Genius |
| [7] | [R1-2100499](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100499.zip) | UE complexity reduction | Nokia, Nokia Shanghai Bell |
| [8] | [R1-2100564](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100564.zip) | UE complexity reduction for Reduced Capability NR devices | ZTE |
| [9] | [R1-2100579](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100579.zip) | On complexity reduction features for NR RedCap UEs | MediaTek Inc. |
| [10] | [R1-2100625](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100625.zip) | Discussion on RedCap features | NEC |
| [11] | [R1-2100660](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100660.zip) | On UE complexity reduction for RedCap devices | Intel Corporation |
| [12] | [R1-2100772](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100772.zip) | UE complexity reduction features for RedCap | Lenovo, Motorola Mobility |
| [13] | [R1-2100823](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100823.zip) | Discussion on UE complexity reduction features | Spreadtrum Communications |
| [14] | [R1-2100843](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100843.zip) | UE complexity reduction | Panasonic Corporation |
| [15] | [R1-2100865](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100865.zip) | UE complexity reduction for Redcap devices | Sony |
| [16] | [R1-2100900](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100900.zip) | Discussion on complexity reduction of reduced capability NR devices | LG Electronics |
| [17] | [R1-2100969](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100969.zip) | Discussion on UE complexity reduction | Asia Pacific Telecom, FGI |
| [18] | [R1-2101049](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101049.zip) | Discussion on UE complexity reduction | CMCC |
| [19] | [R1-2101122](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101122.zip) | Discussion on the complexity reduction for Redcap | Xiaomi |
| [20] | [R1-2101214](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101214.zip) | UE complexity reduction | Samsung |
| [21] | [R1-2101390](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101390.zip) | On UE complexity reduction features for RedCap | Apple |
| [22] | [R1-2101766](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101766.zip) | Complexity Reduction for RedCap Devices(revision of [R1-2101471](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101471.zip)) | Qualcomm Incorporated |
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| [24] | [R1-2101542](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101542.zip) | Discussion on UE complexity reduction | Sharp |
| [25] | [R1-2101619](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101619.zip) | Discussion on UE complexity reduction for RedCap | NTT DOCOMO, INC. |
| [26] | [R1-2101640](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101640.zip) | Potential enhancement for UE complexity reduction | TCL Communication Ltd. |
| [27] | [R1-2101659](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101659.zip) | Discussion on UE complexity reduction | ASUSTeK  |
| [28] | [R1-2101718](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101718.zip) | Discussion on UE complexity reduction | China Unicom |
| [29] | [RP-202933](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Docs/RP-202933.zip) | New WID on support of reduced capability NR devices | Ericsson, Nokia |