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 #2 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 |

The issues in this document are tagged and color coded like this:

1. High Priority
2. Medium Priority

The previous rounds of this email discussion was documented in FL summary #1 in [R1-2101849](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2101849.zip). In this round of the discussion, companies are requested to provide comments/concerns/objections before Monday 1st February 20:00 UTC on the proposals tagged FL3 and FL4.

Follow the naming convention in this example:

* *RedCapFLS2-v000.docx*
* *RedCapFLS2-v001-CompanyA.docx*
* *RedCapFLS2-v002-CompanyA-CompanyB.docx*
* *RedCapFLS2-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 *RedCapFLS2-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapFLS2-v003-CompanyB-CompanyC.checkout*
* CompanyC then has 30 minutes to upload *RedCapFLS2-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 |

Based on the proposals in FL summary #1 in [R1-2101849](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2101849.zip), the following RAN1 agreements were made in an online (GTW) session on Thursday 28th January:

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| Agreements:   * Sharing of the same SSB and CORESET#0 between RedCap and non-RedCap UEs is supported when the bandwidth is no wider than the RedCap UE bandwidth * The initial DL BWP (derived based on MIB/SIB) for RedCap UEs can be the same as the initial DL BWP for non-RedCap UEs at least when the initial DL BWP is no wider than the RedCap UE bandwidth.   + FFS: after initial access, whether a RedCap UE is allowed to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth     - Discuss further whether or not it is also applicable during initial access * The initial UL BWP (derived based on SIB) for RedCap UEs can be the same as the initial UL BWP for non-RedCap UEs at least when the initial UL BWP is no wider than the RedCap UE bandwidth.   + FFS: during and after initial access, whether a RedCap UE is allowed to operate with an initial UL BWP wider than the maximum RedCap UE bandwidth * FFS whether or not to further introduce the following (e.g., for offloading purpose, for differentiation of RedCap vs. non RedCap UEs, for different BWP#0 configuration options, etc.) * Whether an additional CORESET can be configured for scheduling of RACH (msg2 & msg4)/Paging/SI messages for RedCap UEs * Whether the SIB-configured initial DL BWP for RedCap UEs can also be configured to be different from the SIB-configured initial DL BWP for non-RedCap UEs. * Whether the SIB-configured initial UL BWP for RedCap UEs can also be configured to be different from the SIB-configured initial UL BWP for non-RedCap UEs. |

## 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.

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. |
| Intel | N | Same view as Ericsson and Nokia. |
| Vivo | N | Agree with Ericsson and Nokia |
| Huawei | N |  |
| Xiaomi | N | Since there is just very small portion of problematic cases, there is no need to spend effort to redesign the SSB or CORESET#0 and just relying on the implementation solution suffices. For example, when there are Redcap devices in the network, the network could avoid to adopt the problematic configuration. Or even if under the problematic configuration, the Redcap devices can receive the SSB and related COREST#0 in different time occasion with acceptable delay |
| Panasonic | N |  |
| Spreadtrum | N |  |
| OPPO | N |  |
| FUTUREWEI | N |  |
| China Telecom | N |  |
| ZTE | N | No need to improve acquisition time |
| CMCC | N |  |
| Samsung | N | UE implementation can handle the patterns, that SSB +CORESET #0 > RF BW, if configured. |
| Sharp | N |  |
| Qualcomm | N |  |
| TCL | N |  |
| NEC | N |  |
| DOCOMO | N |  |
| CATT | N | Not essential for supporting RedCap UE in FR2. |
| LG | N |  |
| Lenovo, Motorola Mobility | N |  |
| InterDigital | N |  |
| NordicSemi | N |  |
| MediaTek | N |  |
| FL3 |  | Based on the received responses, the following proposal can be considered.  **Medium Priority Proposal 2.1-3:**   * Conclusion: RAN1 does not consider acquisition time improvements for FR2 RedCap UEs with SSB and CORESET#0 multiplexing patterns 2 and 3 as part of this WI. |
| FUTUREWEI3 | Y |  |
| Nokia, NSB | Y |  |
| Qualcomm | Y |  |
| Intel | Y |  |
| DOCOMO | Y |  |
| Huawei, HiSi | Y |  |
| Xiaomi | Y |  |
| LG | Y |  |
| vivo | Y |  |
| Ericsson | Y |  |
| OPPO | Y |  |
| CATT | Y |  |
| TCL | Y |  |
| NEC | Y |  |
| Apple | Y |  |
| CMCC | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Panasonic | Y |  |
| Samsung | Y |  |
| Spreadtrum | Y |  |
| Lenovo, Motorola Mobility | Y |  |

## 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.

**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. | |
| Intel | We expect this to be handled by gNB configuration. Further, we would like to note that (if deemed necessary and supported) multiple initial UL BWPs, e.g., a wide one for non-RedCap and a narrower one for RedCap Ues that is placed towards edge of the carrier, can still be realized without significant impact to PUSCH resource fragmentation for non-RedCap Ues. | |
| Vivo | We would like to prioritize the solution not requiring UE to do RF-retuning. | |
| Huawei | At least network should be able to handle the case if desired, and the RF-retuning is another option that may provide better system performance. | |
| Samsung | If UE can operate in a wider BW, we think RF-retuning can be used.  If dedicated iBWP can be configured, separated configuration of Ros (up to gNB to configure same or different resource from non-Redcap Ues) can ensure all Ros are within UE bandwidth. | |
| Panasonic | We prefer to apply restrictions on the PRACH configurations for RedCap (e.g., network should not configure, and UE does not expect such configurations), only for the condition:   * If the cell allows the access from the RedCap UE, and * If the cell does not configure the RedCap-specific configuration | |
| OPPO | In most cases, it can be solved by gNB configuration, however the flexibility of the network configuration for legacy UE shall not be sacrificed.  Therefore, RF retuning shall be supported for PRACH transmission if the bandwidth of all the Ros is large than Redcap UE’s bandwidth. | |
| FUTUREWEI | We share similar views as Nokia | |
| APT | We share similar view as Qualcomm. We prefer UE not to perform frequency retuning as it may affect UE reception of RAR. | |
| ZTE | gNB can configure dedicated RO and corresponding SSB-RO association pattern if the bandwidth of Ros configured for legacy Ues is wider than the max UE bandwidth of RedCap Ues. | |
| Sharp | To be confined within maximum UE bandwidth, RO for RedCap Ues can be configured by dedicated PRACH configuration even if RACH resources are shared with non-RedCap Ues. | |
| TCL | We share similar views as Nokia. We prefer UE not to do RF-retuning. | |
| Xiaomi | We think both RF-retuning solution and separate PRACH configuration e.g., separate initial UL BWP for Redcap should be considered. It is up to operator’s choice. For example, if the system bandwidth is sufficient, then separate initial UL BWP can be considered. While on the other hand, if frequency resource is limited or the operator want to avoid certain resource fragment, then RF retuning solution can be considered. | |
| NEC | We prefer solutions not to require RF-retuning. RedCap UE should not be expected to be configured with such a case. | |
| DOCOMO | Following two cases should be considered:   * If RedCap Ues have shared initial BWP with non-RedCap Ues: Proper RF-retuning   If RedCap Ues have separate initial BWP from non-RedCap Ues: Dedicated PRACH resources | |
| CATT | For RF-retuning, as long as both (1) gap between SSB and RO and (2) gap between RO and PDCCH for RAR, are sufficient enough for retuning, this option is fine for us.  For restriction on RACH configuration, if no changes on RO mapping rules but just guaranteed by implementation, by adding ‘a RedCap UE does not expect …’, this option is also fine for us. | |
| LG | In our contribution, we suggested the following techniques for further discussion:   * Alt 1: To apply restrictions on the RO configurations for the RedCap Ues * Alt 2: gNB to configure the number N of SSB indexes associated with one RO to be larger than one * Alt 3: gNB to configure 2 initial UL BWPs for RedCap Ues encompassing the 8 FDM Ros and let the RedCap Ues select the initial UL BWP corresponding to the RO associated with the best SSB * Alt 4: To allow the Ros to be configured outside the initial UL BWP and the RedCap UE tunes its frequency to the RO that is associated with the best SSB   At this stage, listing technologies under consideration seems to be a good starting point for further discussion within or starting from this meeting. | |
| Lenovo, Motorola Mobility | We prefer RF-retuning. It is not expected that introduction of RedCap Ues incurs restrictions of RO configurations for legacy Ues. | |
| InterDigital | The network configuration can handle this situation, including by using a dedicated iBWP for RedCap Ues. RF retuning can also be considered. | |
| NordicSemi | This depends greatly on how the following FFS is resolved   * + FFS: during and after initial access, whether a RedCap UE is allowed to operate with an initial UL BWP wider than the maximum RedCap UE bandwidth   We prefer that REDCAP specific initial BWP and REDCAP specific Ros could be configured. REDCAP specific Ros would be anyway needed if Early REDCAP indication is supported. | |
| MediaTek | This could be handled by gNB configuration. | |
| **Company** | **Y/N** | **Comments** | |
| FL4 |  | Based on the received responses, the following proposal can be considered.  **Medium Priority Proposal 2.2-3a:**   * The following options to address the case where a RACH occasion associated with the best SSB falls outside the RedCap UE bandwidth are FFS.   + Option 1: Proper RF-retuning for RedCap * Option 2: Separate initial UL BWP for RedCap Ues * Option 3: gNB configuration (e.g., restrictions on existing PRACH configurations, or FDM-ed Ros) * Option 4: Dedicated PRACH configurations (e.g., Ros) for RedCap Ues | |
| Qualcomm | Y |  | |
| Intel | Y |  | |
| DOCOMO | Y |  | |
| Huawei, HiSi | Y |  | |
| Xiaomi | Y |  | |
| LG |  | Non-of the Options above covers multiple initial UL BWPs for RedCap Ues and and the RedCap Ues select one of the multiple initial UL BWPs containing the RO associated with the best SSB, which is what we were trying to say in Alt.3 of our previous comment above. For this, we would like to propose the following changes:   * The following options to address the case where a RACH occasion associated with the best SSB falls outside the RedCap UE bandwidth are FFS.   + Option 1: Proper RF-retuning for RedCap * Option 2: Separate/multiple initial UL BWP(s) for RedCap Ues * Option 3: gNB configuration (e.g., restrictions on existing PRACH configurations, or FDM-ed Ros) * Option 4: Dedicated PRACH configurations (e.g., Ros) for RedCap Ues   A separate bullet would also work. | |
| Vivo | Y |  | |
| OPPO | Y |  | |
| CATT | Y |  | |
| TCL | Y |  | |
| NEC | Y |  | |
| Apple | Y |  | |
| CMCC | Y |  | |
| Sharp | Y |  | |
| ZTE | Y |  | |
| Panasonic | Y |  | |
| Samsung | Y |  | |
| Spreadtrum | Y |  | |
| Lenovo, Motorola Mobility | Y |  | |
| Nokia, NSB | Y |  | |
| InterDigital | Y |  | |

**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. | |
| Intel | As in our response to Question 2.2-2, we do not see the issue based on consideration of initial UL BWP for RedCap Ues not being wider than RedCap UE’s BW (irrespective of it being shared with non-RedCap Ues or not). | |
| Vivo | We would like to prioritize the solution not requiring UE to do RF-retuning. | |
| Huawei | We prefer to consider proper RF retuning. | |
| OPPO | Not see very strong reason why PUCCH or PUSCH shall be transmitted in an initial UL BWP wider than Redcap UE’s bandwidth.  Initial UL BWP for Redcap UE shall be configured with a bandwidth smaller than its bandwidth. | |
| China Telecom | If RF retuning is applied to avoid the case where a PUCCH (for Msg4 HARQ) or PUSCH (for Msg3) falls outside the RedCap UE bandwidth due to frequency hopping, the additional latency should be considered and evaluated. | |
| ZTE | We show similar view as OPPO.  Shared initial UL BWP can be considered only when an initial UL BWP is not wider than Redcap UE’s bandwidth. | |
| Samsung | We also prefer retuning for this case. eMTC supports frequency hopping outside of a narrow band. We don’t think this will increase burden for UE. However, this could provide better coexistence with legacy and better performance. | |
| Sharp | There is no issue if initial UL BWP for RedCap Ues is ensured to be confined within maximum UE bandwidth (with/without dedicated initial UL BWP) | |
| Qualcomm | We support solutions that do not require RF retuning by RedCap UE.  Early indication based on PRACH is a solution that enables separate scheduling for msg3/msgA PUSCH/PUCCH during initial access of RedCap UE.  On the other hand, disabling (intra-slot) frequency hopping compromises the UL coverage of msg3/msgA PUSCH of non-RedCap UE, which is not desirable. | |
| FUTUREWEI2 | Seems a bit related to the next question, and how some of the FFS progress in the agreement in the last GTW. Would prefer a clear or no decision here (for now) rather than a bunch more options and FFS. | |
| Nokia, NSB | We do not support BWP larger than maximum RedCap UE bandwidth. This question can be revisited once the BWP issue is resolved. | |
| TCL | We prefer UE not to do RF-retuning. | |
| Xiaomi | We are OK with both solutions.  The RF retuning based solution could enable Redcap hop within a large frequency range to achieve better frequency diversity gain. While how to handle the RF retuning gap should be carefully addressed to avoid SE degradation, for example dropping certain symbol in the RF retuning gap is not desirable.  Separate PUCCH configuration could avoid the restriction on the frequency hopping range of non-Redcap and also avoid addition specific handling of the PUCCH or PUSCH of Redcap, e.g., RF retuning can be avoided in this case. | |
| NEC | We prefer solutions not to require RF-retuning. RedCap UE should not be expected to be configured with such a case. | |
| DOCOMO | Following two cases should be considered:   * If RedCap Ues have shared initial BWP with non-RedCap Ues: Proper RF-retuning   If RedCap Ues have separate initial BWP from non-RedCap Ues: No enhancement is necessary | |
| CATT | For Msg3, it may not be a serious problem, since whether hopping or not is controllable and the performance can be improved by link adaptation.  For PUCCH for Msg4, which is always hopping, we prefer not requiring RF-retuning. Performance for control information should be carefully guaranteed. Even symbol-level abandoning due to RF-retuning will increase detection failure probability, especially for short format PUCCH. | |
| LG | The following techniques can be considered for further study and discussion.   * Turning off the frequency hopping * Frequency hopping within the RedCap bandwidth for initial access (e.g., 20MHz for FR1) * RF retuning * Separate initial UL BWP | |
| Lenovo, Motorola Mobility | This depends on whether we will have wider initial UL BWP than UE BW. | |
| CMCC | In most cases, there is no strong motivation to reconfigure a larger initial BWP, which is not power efficient for Ues. In the early phase of network deployment, and when dynamic BWP switching is not support, one larger initial BWP may be configured to avoid frequency fragmentation and make sure UE can fully use the large frequency resource. However, when dynamic BWP switching is support, the 20MHz initial BWP can locate at the edge of carrier to minimize the fragment, and UE switches to a larger BWP when needed, then the motivation become smaller. And when the initial BWP is limited to equal or smaller than 20MHz, RedCap and non-RedCap devices can share the initial BWP without the hopping issues.  And the problem of shared initial BWP is that all the RedCap Ues share the same BWP for initial access with non-RedCap Ues, considering PDSCH and PUSCH data transmission of RedCap Ues, and even some of non-RedCap Ues, the shared initial BWP can be crowed and congestion may happen, that’s why we think separate initial BWP can help, no matter the initial BWP is larger than 20MHz or not.  For the RF retuning, our concern is that it will reduce the demodulation performance of PUCCH and PUSCH. Frequency hopping of such channel is to achieve frequency diversity, and improve coverage, while RF retuning of intra slot transmission may cause two symbols data loss, which leads to the opposite effect. So, the performance loss of RF retuning should be carefully examined. | |
| InterDigital | Agree with NTT DOCOMO’s comment that the solution depends on whether a dedicated initial BWP is present or not. | |
| NordicSemi | Depends on whether separate Ros and/or separate initial BWP are defined for REDCAP or not. | |
| MediaTek | We don’t prefer to do RF-retuning. No need to support BWP larger than maximum RedCap UE bandwidth. | |
| **Company** | **Y/N** | **Comments** | |
| FL4 |  | Based on the received responses, the following proposal can be considered.  **Medium Priority Proposal 2.2-4a:**   * The following options to address the case where a PUCCH/PUSCH occasion falls outside the RedCap UE bandwidth are FFS.   + Option 1: Proper RF-retuning for RedCap   + Option 2: Separate initial UL BWP for RedCap Ues   + Option 3: Separate PUCCH configuration for Redcap (e.g., disabled, or different frequency hopping) | |
| Qualcomm | Y |  | |
| Intel | N | We would like to add another option as:  Option 4: Via gNodeB configuration (e.g., limiting UL initial BWP to BW no more than RedCap UE max BW) | |
| DOCOMO | Y |  | |
| Huawei, HiSi | Y |  | |
| Xiaomi | Y |  | |
| LG | Y |  | |
| vivo | N | We have following comments to the proposal above   1. The issue may only happens during initial access procedure, so it is important to clarify that the PUCCH is the MSG4 HARQ-ACK, and PUSCH is the MSG3 PUSCH. The point is that even if we adopt some special solutions here, we do not think it is proper to continue using it during RRC connected state. 2. Similar as the RACH issue, another option 4 should be added    1. Option 4: gNB configuration (e.g., restrictions on the schedulable BW for MSG 4 HARQ-ACK and MSG3 PUSCH) | |
| OPPO |  | It depends on whether an initial UL BWP larger than Redcap UE’s BW is allowed.  Before the BWP issue is clear, there is no need to discuss this issue. | |
| CATT | Y | Also fine to clarify the use case of PUCCH and PUSCH here, e.g. the origin version of this proposal like ‘**PUCCH (for Msg4 HARQ)’** and **‘PUSCH (for Msg3)**’ | |
| TCL | Y |  | |
| NEC |  | OK to add option 4 mentioned by Intel and vivo | |
| Apple | N | We support adding Opt.4 as proposed by Intel and Vivo. | |
| CMCC | Y | We think gNB always has the flexibility to configure an initial BWP with BW no larger than Redcap UE’s BW, then all the initial acess procedure can be reused.  This propopal talks about the configuration when an initial BWP larger than 20MHz is configured, then the three options can be further studied. | |
| Sharp | Y |  | |
| ZTE |  | Show similar view as OPPO  There is no need to discuss this issue before the BWP issue is clear. | |
| Panasonic | Y |  | |
| Samsung | Y | Also Ok to add option 4 | |
| Spreadtrum |  | We share the similar views with OPPO. | |
| Lenovo, Motorola Mobility | Y |  | |
| Nokia, NSB | N | We do not support initial BWP larger than maximum UE BW. It’s better to agree on the initial BWP bandwidth before considering this. | |
| NordicSemi | Y | If this is kept as FFS, then OK. But this is not a priority question to resolve, first we should sort out whether BWP can be larger than UE REDCAP capability | |
| InterDigital | Y |  | |

## 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. | |
| Vivo | The existing BWP switching mechanism seems sufficient. | |
| Huawei | Need to identify the scenarios that may cause frequency retuning and discuss the necessary scheduling delay or guard period of RF retuning. | |
| Samsung | Existing BWP switching mechanism is not designed for frequently switch. However, to provide better coexistence with non-Redcap UE, Redcap UEs is better to be able to be scheduled within the same frequency range as non-Redcap UEs. So, either Redcap operation in a wider BWP or some faster BWP switching assuming same SCS is beneficial. | |
| OPPO | It depends on whether frequently switch is needed for redcap UE to get frequency hopping gain outside its narrow BWP (configured for power saving). If yes, the BWP switching delay requirement shall be revisited to facilitate such frequency hopping mechanisms. | |
| ZTE | Need to evaluate BWP switching delay for RedCap UEs since the maximum UE bandwidth of RedCap UEs is much smaller than legacy UEs.  Considering the frequency diversity gain of 20MHz is large enough and possible significant spec impacts, we think there is no need to consider RedCap UEs to operate in a BWP wider than maximum UE bandwidth of RedCap Ues in Rel-17. | |
| Qualcomm | In FR1, it is sufficient to support existing BWP switching mechanism for R17 RedCap UE.  In FR2, the following aspects can be considered if time allows:   * Consider switching the UE to a narrow active BWP (NBWP) after initial access is complete. The switching may be:   + Network initiated/controlled (already existing in NR R15/16)   + Implicit: Based on a random selection or some UE ID hashing function   + UE initialed/requested     - UE may send a preferred max UE BW (≤ 100 MHz) to be used after initial access     - UE may send a preferred BWP to be used after initial access * Utilizing BWP hopping to reduce the NB interference effects   + Includes methods to reduce the BWP switching gap effects, e.g.:     - Variable hop BWP time (extension)     - BWP hop skipping/modification     - Define smaller BWP switching times by preconfiguring the hops and by using similar BWP parameters   + Send LS to RAN4 to inquire about switching gaps between preconfigured BWPs with the same configurations (no DCI reading) | |
| FUTUREWEI2 | It may be worth asking RAN4 about whether faster BWP switching is possible | |
| Nokia, NSB | The existing BWP switching mechanism is sufficient. | |
| Xiaomi | straightforward BWP framework for Redcap is that a narrow BWP is configured for Recaps so that the Redcap devices could monitor all the frequency resource in the BWP. While we see the following drawbacks:   * some loss in frequency diversity / frequency selective gain * within a narrow BWP, it is not efficient to include SSB in each BWP, then the Redcap would switch to the BWP including SSB to do the SSB measurement for RLM/RRM   To address the above drawbacks, we think the following two directions worth consideration  - Direction 1: Support configuring BWP larger than the maximum UE bandwidth. RF retuning can be utilized to different resource of the wide BWP  - Direction 2: Optimize the BWP framework to reduce the switching gap | |
| Intel | A simplified BWP hopping framework can be beneficial to recover against lost diversity via some variations in the channel and interference. In this context, numerology and most RRC configurations can be maintained the same across the BWPs. In this regard, we would also support sending an LS to RAN4 on switching times under such conditions and with potential bounding of the “hopping distance” for the BWP center frequencies. | |
| NEC | The existing BWP switching mechanism should be sufficient for reduced capability devices. | |
| DOCOMO | The existing BWP switching mechanism is sufficient | |
| CATT | From mechanisms point of view, the existing BWP switching mechanisms should be sufficient (e.g. RRC configured-based, DCI-based, timer-based).  Maybe the switching time can be different, e.g. a larger switching time may be needed, if confirmed by RAN4. | |
| LG | Don’t see any issue to support RedCap with the existing BWP switching mechanism. Faster BWP switching may be helpful for NR devices in general, which can be discussed separately perhaps not in this WI. Frequency hopping across BWP has little motivation compared to eMTC as the bandwidth of RedCap is same as normal LTE devices which is much larger the eMTC. These are considered as not essential but nice-to-have features that can be sought along with the evolution. | |
| Lenovo, Motorola Mobility | The existing BWP switching mechanism maybe sufficient. We are also open for additional BWP switching if beneficial. | |
| CMCC | The existing BWP switching mechanism is sufficient. | |
| InterDigital | The existing mechanism may be sufficient; switching time may be investigated further. | |
| NordicSemi | Existing BWP switching is enough, however, assuming that reduced capability UE will be capable to support configuration of many non-overlapping BWPs is not very realistic. | |
| MediaTek | We think it is sufficient to support existing BWP switching mechanisms. | |
| **Company** | **Y/N** | **Comments** |
| FL4 |  | Based on the received responses, the following proposal can be considered.  **Medium Priority Proposal 2.3-1a:**   * For BWP switching for RedCap Ues:   + FFS: Whether the currently defined BWP switching delay is sufficient to accommodate RF retuning delay, based on RAN4 confirmation/feedback for FR1 and FR2   + FFS: Whether inter-BWP frequency hopping is supported (for diversity gain) |
| Qualcomm | Y |  |
| Intel | Y |  |
| DOCOMO | Y |  |
| Huawei, HiSi | Y |  |
| Xiaomi | N | The first FFS bullet is not clear to us. In which case, the RF retuning would happened. Does it intend for the case of configuring a wide BWP larger than Redcap’s UE bandwidth ? |
| LG |  | For the first FFS, we don’t see any issue to support RedCap with the existing BWP switching mechanism. If what we are trying to do here is an enhancement of the existing BWP switching, then it may be a topic for NR devices in general. However, given the formulation from the FL, with the understanding the intention is to get confirmation/feedback from RAN4, we can live with the first FFS.  For the second FFS, we think the frequency hopping across BWP has little motivation compared to eMTC as the bandwidth of RedCap is same as normal LTE devices which is much larger the eMTC. As we don’t expect substantial gain from this, and also don’t think this is essential to make RedCap work, we prefer to remove the second FFS. As companies can still bring in results to show the benefits and/or gains without the FFS, we can continue discussion anyway. |
| Vivo | N | The 1st FFS is too early to conclude, RAN1 should first agree the use case for RF retuning beyond the existing BWP switching, if agreed, ask RAN4 about whether existing switching time can be reused  The 2nd FFS is not agreeable. The inter-BWP frequency hopping was explicitly discussed during study item and in the WID drafting during RAN#90e, it was not included in the current WID so out of scope. |
| OPPO | Y | BWP hopping is important for redcap UEs:   1. to reduce the NB interference effects 2. get frequency diversity gain when very small BWP is configured for power saving |
| CATT |  | About the 2nd FFS, it is still unclear what is the essential difference between ‘inter-BWP frequency hopping’ and ‘BWP switching’ from RAN1 specification point of view. |
| TCL | Y |  |
| NEC | Y |  |
| Apple |  | We share the view to clarify the targeted use cases first to make potential RAN4 LS more concrete and solid. |
| CMCC | Y |  |
| Sharp | Y |  |
| ZTE |  | The 1st FFS is needed. Considering the reduced capability of RedCap UEs, there is a need to confirm whether the legacy BWP switching delay values are sufficient for RedCap UEs due to RF retuning.  We don’t think there is a need to study inter-BWP frequency hopping for RedCap UEs. Inter-BWP frequency hopping increases the complexity of RedCap UEs and is harmful for the UE’s power consumption. |
| Panasonic | Y |  |
| Lenovo, Motorola Mobility | Y |  |
| Nokia, NSB |  | On the 1st FFS, we are not clear why existing BWP switching delay would not be applicable to RedCap UE. We did not discuss this during our complexity reduction so we feel that RedCap UE should then support existing BWP switching delay.  On the 2nd FFS, we do not think inter-BWP hopping is needed for frequency diversity gain given RedCap 20/100 MHz BW support. |
| NordicSemi | N | If asking RAN4 about further relaxation BWP switching timelines, we should ask for both Dynamic and RRC based BWP switch. Only RRC-based is mandatory in R15/R16  If Vivo is right about BWP hopping RAN discussion, then it should not be discussed in RAN1. |
| InterDigital | Y |  |

## 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?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Comments** | |
| Ericsson | None | |
| vivo | None | |
| Huawei | Same answer as that for 2.3-1. | |
| Samsung | We suggest to discuss whether support UE operates in a wider BWP or not, and the corresponding enhancements:  For UE operates in UE-specific BWP no larger than RF bandwidth, CSI acquisition outside active BWP across the entire carrier BW is needed. Otherwise, it’s impossible for the NW to switch RedCap UEs to an ideal BWP with best channel condition. Enhancement such as SRS transmissions or CSI report for link adaptation outside active BWP can be considered.  For UE operates in wider BWP, at least the following can be further studied: retuning time, hopping rule, resource allocation, CSI measurement and report. | |
| China Telecom | None | |
| Sharp | None | |
| Qualcomm | In FR1, we don’t see a need to prioritize any other topic.  In FR2, the following aspects can be considered if time allows:   * Reusing RS’s for different purposes (e.g., use DMRS for beam management) * Reusing RS between RedCap and non-RedCap UEs (e.g., CSI-RS duplication may be reduced by sharing WB RS with NB RedCap) * Pre-configurations for certain message types (e.g., DCI-less/preconfigured re-tx resources) * On-demand or event-based operation (e.g., event-based L1-meas reports, UE requested/on-demand CORESETs | |
| FUTUREWEI2 | None | |
| Nokia, NSB | None | |
| TCL | None | |
| Xiaomi | Similar consideration, we think support UE operates in a wider BWP should be studied. Wide-band BWP operation could provide better channel selective/ frequency diversity gain. In addition, RF retuning within a wide BWP incurs less switching time when performing the SSB based measurement. | |
| Intel | None | |
| OPPO | If Redcap UE is configured with narrow BWP for power saving, the frequency diversity gain will be impacted. We propose to study mechanism to get frequency diversity gain, such as frequency hopping. | |
| NEC | None | |
| DOCOMO | As a design principle, fragmentation of PUSCH resource for non-RedCap UEs should be avoided especially when a non-RedCap UE uses DFT-s-OFDM | |
| CATT | None | |
| LG | None | |
| CMCC | None | |
| InterDigital | None. | |
| **Company** | **Y/N** | **Comments** |
| FL4 |  | Based on the received responses, the following proposal can be considered.  **Medium Priority Proposal 2.5-1a:**   * For RRC-configured BWPs for RedCap Ues:   + FFS: Whether to support RedCap UE operation in a BWP wider than the RedCap UE bandwidth   + FFS: Whether to support mechanisms for frequency diversity if RedCap Ues operate on BWP not wider than the RedCap UE bandwidth   + FFS: Whether and how to avoid or reduce fragmentation of PUSCH resources for non-RedCap Ues |
| Qualcomm | Y |  |
| Intel | Y |  |
| DOCOMO | Y |  |
| Huawei, HiSi | Y |  |
| Xiaomi | Y |  |
| LG | N | We think the first two FFS above should not be prioritized. They are not essential and the benefits are not clear yet. For the third FFS, it feels it is kind of a design principle taking into account the coexistence with legacy UEs. That principle has been there form the start and is quite clear from the WID. We don’t think this proposal is needed. |
| Vivo | N | The 1st and 2nd FFS are not agreeable. The UE operation in a wider BWP was explicitly discussed during study item and in the WID drafting during RAN#90e, it was not included in the current WID so out of scope.  Fine to keep the 3rd FFS as it somehow related to the coexistence of redcap UEs and non-redcap UEs. But technically we do not think this is a new problem created by Redcap, since Rel-15 we support configuring different UL BWP sizes for different UEs, so gNB should be able to handle the “PUSCH fragmentation” issue, if exists. |
| OPPO | Partially Y | We don’t see the need to configure a large BWP than Redcap UE’s BW when the UE in RRC connected states. |
| CATT |  | The 1st and 2nd FFS are some detailed mechanism while the 3rd FFS is more like a design principle. This makes it unclear what is the attempt for this proposal. |
| TCL | Y |  |
| NEC | Y |  |
| Apple | N | We do not see the justification to configure a UE-specific BWP that is larger than the reported UE capability.  On the 2nd FFS, it is better to clarify ‘frequency diversity’ operation, e.g., across different Redcap BW within a CC or something else. |
| CMCC |  | The second FFS is not clear enough. If it means the inter-BWP hopping, there is already one similar FFS in Proposal 2.3-1a. |
| Sharp | Y |  |
| ZTE | N | For 1st bullet, we think there is no need to configure a large BWP than Redcap UE’s BW when the UE in RRC\_Connected.  For 2nd bullet, existing mechanisms for frequency diversity can be reused for RedCap UEs if BWP is not wider than the RedCap UE bandwidth. There is no need to study RedCap dedicated solutions.  For the 3rd bullet, ‘PUSCH fragmentation’ of non-RedCap UEs is not a new issue. Enhancement in RedCap WID cannot resolve the ‘PUSCH fragmentation’ issue of non-RedCap UEs. |
| Panasonic | Y | We support the proposal 2.5-1a as it is.  We also agree to study whether to support BWP wider than RedCap UE BW. Our view is that wider BWP is beneficial for more flexible frequency resource allocation and then the better co-existence with the non-RedCap UE. |
| Samsung |  | We think co-existence is within the scope of this WID. Therefore, we should look into the solutions, to avoid fragment the resource for non-Redcap UEs.  In addition, several companies suggested to consider faster BWP switching delay. Therefore, we suggest the following change:  **Medium Priority Proposal 2.3-1a:**   * For BWP switching for RedCap UEs:   + FFS: Whether the currently defined BWP switching delay is sufficient to accommodate RF retuning delay, based on RAN4 confirmation/feedback for FR1 and FR2   + FFS: Whether can acheive faster switching delay assuming the same SCS, based on RAN 4 confirmation/feedback for FR1 and FR2   + FFS: Whether inter-BWP frequency hopping is supported (for diversity gain) |
| Spreadtrum | Partially Y | It is not necessary to support a larger DL BWP than Redcap UE’s BW.  FFS for UL BWP. |
| Lenovo, Motorola Mobility | Y |  |
| Nokia, NSB |  | We don’t support 1st and 2nd bullets. We also don’t really see a need for 3rd bullet but are OK to consider it.  On the 1st bullet, we do not see the justification to configure BWP wider than the maximum UE BW. On the 2nd bullet, we think 20/100 MHz is large enough to provide frequency diversity gain. If UE is configured on narrow BW for power saving, it can be switched to wider BW for data transmission to achieve frequency diversity. |
| InterDigital | Y |  |

# Reduced minimum number of Rx branches

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

|  |
| --- |
| * 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?**

|  |  |  |
| --- | --- | --- |
| **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. | |
| China Telecom | None. | |
| Intel | None beyond the potential ones already mentioned in the question. | |
| CATT | None | |
| Sharp | None. | |
| Vivo | None. And there is no need to support early identification due to Reduced Rx | |
| NEC | None. | |
| Huawei | The applicability of existing features/R17 CE WI techniques for RedCap UEs require some discussion. | |
| Xiaomi | Same view with DOCOMO | |
| Samsung | We think PDCCH blocking rate, PDCCH overhead need to be addressed. | |
| Panasonic | None | |
| LG | None beyond what FL mentioned (possible early UE type identification and possible coverage recovery related functionality). | |
| OPPO | Possible coverage recovery related functionality to compensate for reduced antenna gain loss, e.g., for wearbles. | |
| InterDigital | None. | |
| Lenovo, Motorola Mobility | None | |
| FUTUREWEI | No significant impacts except for early identification and possible coverage recovery enhancements | |
| SONY | Agree with Qualcomm that for FR2, UE antenna configuration (polarization/panels) may need to be reported to the gNB.  Agree with the baseline proposal (possible early identification and possible coverage recovery) | |
| APT | None | |
| Apple | None. | |
| MediaTek | None | |
| FL1 | Based on the received responses, the following proposal can be considered. Possible early UE type identification and possible coverage recovery related functionality are not captured in the proposal since these aspects are pending further RAN plenary decisions in RAN#91e.  **High Priority Proposal 3.1a:**   * For reduced minimum number of Rx branches in FR1 and FR2 frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports:   + FFS: need for solutions to reduced PDCCH blocking and/or overhead   + FFS: need for UE antenna configuration reporting to gNB in FR2 | |
| Qualcomm | We are ok with FL1 proposal as above | |
| InterDigital | Y | |
| Intel | Y | |
| DOCOMO | We support FL1 proposal | |
| Nokia, NSB | Y | |
| vivo | The first FFS sub-bullet is beyond the current WID scope thus should not be included | |
| FUTUREWEI | We understand the intention of the second FFS given Qualcomm’s response, but as written it may imply that 1RX or 2RX itself does not need to be reported. So a small clarification may be needed. | |
| CATT | Is the first FFS sub-bullet reopening the enhancement on PDCCH monitoring reduction? | |
| OPPO | Y | |
| ZTE | Y | |
| LG | We are not okay with the proposal.  In our opinion, the two FFS points are much less motivated and supported by companies than the early UE type identification and coverage recovery related functionality. So, we don’t see the need to agree on the Proposal 3.1a with the only 2 FFS points. | |
| Xiaomi | Y | |
| TCL | Y | |
| NEC | Y | |
| CMCC | Y | |
| Lenovo, Motorola Mobility | Fine with FL’s proposal | |
| Samsung | OK. | |
| Sharp | Y | |
| China Unicom | Y | |
| Ericsson | We are fine with the proposal. | |
| Huawei, HiSi | Y | |
| **Company** | **Y/N** | **Comments** |
| FL2 |  | Based on the received responses, the following proposal can be considered. Possible early UE type identification and possible coverage recovery related functionality are not captured in the proposal since these aspects are pending further RAN plenary decisions in RAN#91e.  **High Priority Proposal 3.1b:**   * For reduced minimum number of Rx branches in FR1 and FR2 frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports:   + FFS: need for solutions to reduced PDCCH blocking and/or overhead   + FFS: need for UE antenna/branch configuration reporting to gNB |
| Qualcomm | Y |  |
| FUTUREWEI2 |  | We did not really get an answer to our question, is the FL intent that whether a UE is 1RX or 2RX does not need to ever be known by the gNB?  If we can’t word it properly also OK to wait till next meeting for this one when we have the full reduced RX picture. |
| Nokia, NSB | Y |  |
| FL |  | In response to Futurewei’s comment:  There is no FL intention to preclude gNB knowledge of the number of UE Rx branches. (Can an FFS really preclude anything?)  Note that the wording was updated in Proposal 3.1b compared to Proposals 3.1a to say “UE antenna/branch configuration” instead of “UE antenna configuration” as an attempt to address Futurewei’s concern. |
| Xiaomi | Y |  |
| Ericsson | Y |  |
| vivo | N | As commented before, the first FFS bullet is beyond the WID scope thus should be removed. |
| Intel | Y |  |
| LG | N | We are still not okay with this proposal. Nothing has changed.  Other than the possible early UE type identification and possible coverage recovery related functionality, we see the motivation of enhancement of the first FFS is too weak. Same for the second FFS which is not even clear what is intended. |
| APT | Y |  |
| FUTUREWEI2 |  | Thanks for the FL attempt to clarify. We thought the Qualcomm intent was the need for antenna configuration information beyond the number of RX branches. But the FL clarification still appears to leave reporting the number of branches up in the air. Perhaps the FL intent is to want RX branches to only be reported as part of early identification? Anyway, since the FFS is not clear and we have #RX clarifications at next RAN anyway, let us wait on that FFS. |
| NEC | Y |  |
| DOCOMO | Y | We fail to understand why the first FFS is out of WID scope or its motivation is too weak. As clearly stated in WID, coexistence with non-RedCap UEs is to be ensured. TR 38.875 captures following in Clause 7.2.4: Analysis of coexistence with legacy Ues for reduced number of Rx antenna ports.  If higher PDCCH aggregation levels are used for RedCap Ues, the PDCCH blocking rate for legacy Ues may be increased if they share the same CORESET.  Obviously, first FFS is not out of WID scope and should be addressed |
| China Telecom |  | We are fine to wait till the next RAN meeting to make the final decisions on the reduced minimum number of Rx branches. |
| CATT | Y | Maybe OK to further discuss whether the motivations are strong enough. |
| Samsung | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Lenovo, Motorola Mobility | Y |  |
| CMCC | Y |  |
| InterDigital | Y |  |
| MediaTek | Y | Fine with the proposal |
| FL3 |  | Based on the received responses, the following proposal can be considered. Possible early UE type identification and possible coverage recovery related functionality are not captured in the proposal since these aspects are pending further RAN plenary decisions in RAN#91e.  For the FFS on the potential need for solutions to reduced PDCCH blocking and/or overhead, different views were expressed in the responses. Two responses argue that it is not in the WI scope or that the motivation is too weak, whereas one response argue that the FFS is in the WI scope.  The FFS on the potential need for UE antenna/branch configuration reporting to gNB has been removed since some responses expressed that it is better treated after the WI objective on reduced minimum number of Rx branches has been further clarified in RAN#91e.  **High Priority Proposal 3.1c:**   * For reduced minimum number of Rx branches in FR1 and FR2 frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports:   + FFS: need for solutions to reduced PDCCH blocking and/or overhead |
| FUTUREWEI3 | Y |  |
| Nokia, NSB | Y |  |
| Qualcomm |  | Based on the WID for R17 RedCap devices, it is agreed that:  *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.*  Since RedCap UE with 1 RX or 2 RX branches will be supported on frequency bands where a legacy NR UE is required to be equipped with a minimum of 2 Rx antenna ports, it is necessary for gNB to differentiate them in the UE capability query/report after initial access.  Therefore, we support FL2 proposal as it is. |
| Intel | Y | Our understanding on reporting number of supported Rx branches can be discussed as part of UE features discussions at a later stage in the WI. |
| DOCOMO | Y |  |
| Huawei, HiSi | Y |  |
| Xiaomi | Y |  |
| LG |  | The proponent of the FFS part seems to assume that the performance of 1 Rx UE’s have some issues in coverage compared to 2 Rx UEs. This is related to RAN plenary discussion on the number of Rx for NR 4-Rx bands. From our perspective, this is not clear yet and in a use cases such as smart wearables, we are not sure if there is significant performance different to change the AL level. We still don’t see the motivation is strong.  And we think the “and/or overhead” in the FFS should be removed unless the intention of it is clear explained and understood. |
| Vivo |  | Regarding the “FFS: need for solutions to reduced PDCCH blocking and/or overhead”, we can understand DOCOMO’s argument. However, procedure wise, reduced PDCCH blocking was not captured in the WID so strictly speaking it is out of scope. For this particular case, we would be fine to keep the FFS if we are the only company who had concern, but we are worried if this would encourage other enhancements that are not explicitly mentioned in the WID (although they may have been discussed during SI phase without recommendation).  Regarding “FFS: need for UE antenna/branch configuration reporting to gNB”, we agree with Qualcomm and would like to keep it. |
| Ericsson | Y |  |
| OPPO |  | For a pure FFS proposal, we don’t see the necessity to agree on it.  We propose to firstly check whether the PDCCH blocking and/or overhead exists. |
| CATT | Y |  |
| TCL | Y |  |
| NEC | Y |  |
| Apple |  | Support to study solutions for PDCCH capacity enhancement for Redcap use cases. On the other hand, agreement with only FFS is less progress. |
| CMCC | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Panasonic | Y |  |
| Samsung | Y |  |
| Lenovo, Motorola Mobility | Y |  |

# Maximum number of DL MIMO layers

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

|  |
| --- |
| * 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?**

|  |  |  |
| --- | --- | --- |
| **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. | |
| China Telecom | None. | |
| Intel | None at the moment (possible clarifications for 38.214 could be considered at a later stage). | |
| CATT | We think simple description on DL MIMO layer restriction is enough, e.g., ‘A RedCap UE is not expected to be indicated with more than Y DL MIMO layers…’ where Y depends on number of Rx branches. Detailed wording can be FFS. | |
| Sharp | None. | |
| Vivo | None | |
| NEC | None | |
| Huawei | PDCCH enhancements including e.g. compact DCI or group-wise DCI, due to the simplification of MIMO layers from RedCap UEs on some DCI fields. | |
| Xiaomi | None | |
| Samsung | We don’t expect significant impacts. But some simplification including CSI measurement/report might need to be clarified. | |
| Panasonic | None | |
| Spreadtrum | None | |
| LG | None. Maybe some impact on the definition on the UE type. | |
| OPPO | None | |
| InterDigital | None. | |
| Lenovo, Motorola Mobility | None | |
| FUTUREWEI | No significant impact expected | |
| SONY | None | |
| APT | None | |
| Apple | None. Two-layers MIMO communication supposed to be supported already since Rel-15. | |
| FL1 | Based on the received responses, the following proposal can be considered. Possible impact on UE type definition is not captured in the proposal since it belongs more under agenda item 8.6.2 which should not be discussed in this meeting.  **High Priority Proposal 4.1a:**   * For relaxed maximum number of DL MIMO layers:   + FFS: need for modification of DCI definition/processing   + FFS: need for modification of CSI measurement/reporting | |
| Qualcomm | We are ok with FL1 proposal as above | |
| InterDigital | Y | |
| Intel | Y | |
| DOCOMO | We are fine with FL1 proposal | |
| Nokia, NSB | Y | |
| vivo | Y | |
| FUTUREWEI | Y | |
| CATT | OK for us. | |
| OPPO | Y | |
| ZTE | Y | |
| LG | We are not okay with the proposal.  A clear majority view is that no or very minor specification work is needed. But the current formulation feels like we are listing potential enhancements based on a few feedbacks for minor enhancements. | |
| Xiaomi | Y | |
| TCL | Y | |
| NEC | Y | |
| CMCC | Y | |
| Lenovo, Motorola Mobility | Fine with FL’s proposal | |
| Samsung | Y | |
| Sharp | Y | |
| China Unicom | Y | |
| Ericsson | We are fine with the proposal. | |
| Huawei, HiSi | Y with modifications. The terminologies of ‘DCI definition/processing’ might be too broad. Suggest:   * For relaxed maximum number of DL MIMO layers:   + FFS: need for modification of DCI fields/formats ~~definition/processing~~   + FFS: need for modification of CSI measurement/reporting | |
| **Company** | **Y/N** | **Comments** |
| FL2 |  | Based on the received responses, the following proposal can be considered. Possible impact on UE type definition is not captured in the proposal since it belongs more under agenda item 8.6.2 which should not be discussed in this meeting.  **High Priority** **Proposal 4.1b:**   * For relaxed maximum number of DL MIMO layers:   + FFS: need for modification of DCI fields/formats   + FFS: need for modification of CSI measurement/reporting |
| Qualcomm | Y |  |
| FUTUREWEI2 | Y |  |
| Nokia, NSB | Y |  |
| Xiaomi | Y |  |
| Ericsson | Y |  |
| vivo | Y |  |
| Intel | Y |  |
| LG |  | Don’t think this agreement is needed. But, won’t object if we are only company.  Our preliminary thought is that some clarification wording is enough for both DCI fields/formats and CSI measurement/reporting. |
| APT | Y |  |
| OPPO | Y |  |
| NEC | Y |  |
| DOCOMO | Y |  |
| China Telecom | Y |  |
| CATT | Y | Maybe OK to further discuss whether the motivations are strong enough. |
| Samsung | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Huawei, HiSi | Y |  |
| Spreadtrum | Y |  |
| Lenovo, Motorola Mobility | Y |  |
| CMCC | Y |  |
| InterDigital | Y |  |
| MediaTek | Y |  |
| FL3 |  | Based on the received responses, it seems that Proposal 4.1b can be agreed. |
| Qualcomm | Y |  |
| Huawei, HiSi | Y |  |
| Samsung | Y |  |

Based on Proposal 4.1b above, the following RAN1 agreements were made on the RAN1 reflector:

|  |
| --- |
| Agreements:   * For relaxed maximum number of DL MIMO layers:   + FFS: need for modification of DCI fields/formats   + FFS: need for modification of CSI measurement/reporting |

# Relaxed maximum modulation order

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

|  |
| --- |
| * 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?**

|  |  |  |
| --- | --- | --- |
| **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. | |
| China Telecom | None. | |
| Intel | None. | |
| CATT | None | |
| Sharp | None. | |
| Vivo | None | |
| NEC | None | |
| Huawei | None. Low-SE MCS can be an optional UE feature as legacy UEs. | |
| Xiaomi | No critic specification impact. But we are open to discuss whether support the lower-SE MCS table | |
| Samsung | None | |
| Panasonic | None | |
| Spreadtrum | None | |
| LG | None | |
| OPPO | None | |
| InterDigital | None. | |
| Lenovo, Motorola Mobility | None | |
| FUTUREWEI | Similar views as Qualcomm | |
| SONY | None | |
| APT | None | |
| Apple | None | |
| FL1 | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 5.1a:**   * For relaxed maximum modulation order:   + FFS: support/applicability of the lower-SE MCS table in 38.214 during initial access | |
| Qualcomm | We are ok with FL1 proposal as above | |
| InterDigital | Y | |
| Intel | Y | |
| China Telecom | Y | |
| DOCOMO | We are fine with FL1 proposal | |
| Nokia, NSB | Y | |
| vivo | We are not sure about the FFS bullet. Our understanding is that lower-SE MCS table cannot be used for legacy UEs during initial access (has to be configured after initial access). | |
| FUTUREWEI | Y | |
| CATT | OK for us. | |
| OPPO | Y | |
| ZTE | Y | |
| LG | Okay. But don’t see a need to have this agreement with the minor, if any, enhancement only. | |
| Xiaomi | Do we need to limit the use case of lower-SE MCS table in initial access? We think the lower-SE MCS table can be used after initial access as well. | |
| TCL | Y | |
| NEC | Y | |
| CMCC | Y | |
| Lenovo, Motorola Mobility | Fine with FL’s proposal | |
| Samsung | We don’t see the need to support low SE MCS table.  We think a conclusion to conclude is more proper, such as:  **Current RAN 1 spec can support relaxed maximum DL modulation order in FR1 for RedCap devices.** | |
| Sharp | Y | |
| China Unicom | Y | |
| Ericsson | We are fine with the proposal. | |
| Huawei, HiSi | N.  The current FFS in the proposal has nothing to do with spec impact due to relaxed modulation order (from mandatory 256QAM to 64QAM). In our view it is about to extend some existing features supported by legacy UEs as optional after initial access to RedCap UEs during initial access, for coverage purpose. We suggest to discuss all coverage related proposals and its relationship with existing features/R17 CE WI features at a proper place/timing. | |
| **Company** | **Y/N** | **Comments** |
| FL2 |  | As commented by Huawei, possible coverage recovery related functionality is not expected to be discussed in this meeting since this aspect is pending further RAN plenary decisions in RAN#91e. Instead, the following potential conclusion proposed by Samsung can be considered.  **High Priority Proposal 5.1b:**   * Conclusion: Current RAN1 specifications can support relaxed maximum DL modulation order in FR1 for RedCap devices. |
| Qualcomm |  | We don’t think this conclusion is necessary. This is clear from the WID already. |
| FUTUREWEI2 | N | We are OK to wait to discuss. The modulation tables for RedCap need to be discussed, and this is an example of a feature beneficial to RedCap UEs that is currently optional that should probably be mandatory. As Qualcomm mentioned, it could also be tied to initial access. The picture for early identification and 1RX will be more clear after next RAN. |
| Nokia, NSB | Y | We are fine to have the conclusion |
| Xiaomi |  | OK to discuss the application of lower-SE MCS table in latter phase.  But at current stage, since the MCS table to be used during and after initial access is not agreed, so we don’t need to rush to get a conclusion. We could further discuss the MCS table to be used for Redcap based on the possible conclusion of 1Rx or coverage recovery to be made during next RANP meeting. |
| Ericsson | Y |  |
| vivo | Y |  |
| Intel | Y |  |
| LG | Y | We are supportive of having this type of conclusion for clarification especially for RedCap. We would like to note that this is not in the scope of the reduced DL modulation order. This is more related to coverage recovery thing which we don’t have to discuss under this feature. We are okay to not agreeing on anything related to this issue in this sense. |
| APT | Y | We are fine with the conclusion. |
| OPPO | Y |  |
| NEC | Y |  |
| DOCOMO | Y |  |
| China Telecom | Y | We are fine to have this conclusion if it is needed. |
| CATT | Y |  |
| Samsung | Y | We prefer a conclusion. The conclusion has more information than WID, i.e., no spec change is needed to support this feature. |
| Sharp | Y |  |
| ZTE |  | We don’t think this conclusion is necessary. |
| Huawei, HiSi | N | This conclusion does not seem to help the progress. As several companies mentioned the original proposal relates to coverage and somewhat the intention of the original proposal is not relevant to modulation order relaxation. On top of that, we think a more general discussion/understanding may be needed, like whether all existing optional features are be default applicable to RedCap UEs unless specifically issues are identified, which can be discussed case by case.  For the discussion comes to the applicability of initial access, it even requires more attention since early identification may be needed – too many dimensions for identification may not be desirable.  Given no benefits that the proposed conclusion can offer and we will anyway discuss other optional features, we prefer not to discuss this. (and by default, if no issue identified to the end of the WI, it could be the case as proposed). |
| Lenovo, Motorola Mobility | Y |  |
| CMCC | Y |  |
| InterDigital | Y |  |
| MediaTek | Y |  |
| FL3 |  | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 5.1c:**   * For relaxed maximum modulation order:   + FFS: which one of the currently defined MCS tables that is the default MCS table for RedCap UEs not supporting 256QAM |
| FUTUREWEI3 | Y | Also OK to wait to discuss |
| Nokia, NSB |  | We are not quite sure why this FFS is considered under relaxed maximum modulation order. In our view the issue of default MCS table is related to coverage recovery and is not dependent on whether UE supports 256-QAM or not.  So we think the previous proposal 5.1b is good and this proposal is not really relevant to relaxed maximum modulation order. |
| Qualcomm | Y | An editorial suggestion for the FFS part:  o FFS: which one of the currently defined MCS tables ~~that~~ is the default MCS table for RedCap UEs not supporting 256QAM |
| Intel | Y |  |
| DOCOMO | Y | OK to further discuss FFS part, but should be postponed to discuss until next meeting as it is related to coverage perspective. |
| Huawei, HiSi | N | The alt does not change the reasons for NOT support: there is no issue for the current default tables to be used, due to relax of DL modulation order. So it is irrelevant. |
| Xiaomi | N | It seems there is no relationship between the default MCS table configuration and the support of 256 QAM. Even for UE supporting 256 QAM, how to define the default MCS table is also one issue to be discussed.  We are OK to discuss this issue in next meeting when the situation of coverage recovery is stable and clear. |
| LG |  | We also prefer the previous one, Proposal 5.1b. |
| vivo | Y | We are fine with the latest proposal above |
| Ericsson | Y | We will also be fine to wait. |
| OPPO | Y | We are fine to discuss this issue till next meeting when the coverage recovery is clear. |
| CATT | Y |  |
| TCL | Y |  |
| NEC | Y |  |
| CMCC | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Panasonic | Y |  |
| Samsung |  | We prefer the original proposal 5.1b. The MCS table defined in current spec has no issue. |
| Spreadtrum | Y |  |
| Lenovo, Motorola Mobility |  | We prefer the original proposal 5.1b. |

# 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 and defined for UE not capable of full duplex in FR1 is equal to 13.02, 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 after the end of the last received downlink symbol in the same or different cell within the group of cells where 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 after the end of the last transmitted uplink symbol in the same or different cell within the group of cells where 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 after the end of the last received downlink symbol in the same cell where 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 after the end of the last transmitted uplink symbol in the same cell where is given by Table 4.3.2-3.  Table 4.3.2-3: Transition time and   |  |  |  | | --- | --- | --- | | **Transition time** | **FR1** | **FR2** | |  | 25600 | 13792 | |  | 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 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 |  |
| China telecom | Y | We slightly prefer Option 1. The existing switching times for UE not capable of full duplex in TS 38.211 is less than 1 OFDM symbol. Before making the decisions on whether reusing existing switching times or define new one, it would be better to ask RAN4’s confirmation. |
| Intel | Y | Option 1 is preferred. |
| CATT | Y | Though both options may work, we prefer Option 1 for simplicity for NR spec. |
| Sharp | Y | Option 1 is preferred. |
| Vivo | Y | Option 1 and the need to define new symbol-level switching time is not clear. |
| Huawei | Y |  |
| Xiaomi | Y | RAN4 should be the WG to make the decision. |
| Samsung | Y | We prefer option 1 |
| Panasonic | Y |  |
| Spreadtrum | Y | Option 1 is preferred. |
| LG | Y | Two options are enough for further consideration for now.  For comparison between the two options, further clarification would be helpful on what the LTE HD-FDD Type-A approach means in the context of defining/determining the switching time. |
| OPPO | Y | Option 1 is preferred. |
| InterDigital | Y | We prefer Option 1. |
| FUTUREWEI | Y |  |
| SONY | Y | Both options should be considered at the moment. We expect that RAN4 would be involved in the decision. |
| APT | Y | Option 1 is preferred. We prefer to send LS to RAN4 and wait for RAN4 feedback. |
| Apple | Y | Option.1 |
| FL1 | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.1a:**   * For HD-FDD switching time, down-select between the following options in a future meeting, based on RAN4 feedback:   + 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.   + Option 2: Reuse LTE HD-FDD Type-A approach. | |
| Qualcomm | We are ok with FL1 proposal as above | |
| InterDigital | Y | |
| Intel | Y | |
| China Telecom | Support FL’s proposal. | |
| DOCOMO | We support FL1 proposal | |
| Nokia, NSB | Y | |
| vivo | N.  In current spec (38.211) the switching time for half-duplex UE has been defined, and WID says we should minimize the impact. So we do not see the need to reopen the discussion for new switching time definition.  *A UE not capable of full-duplex communication is not expected to transmit in the uplink earlier than after the end of the last received downlink symbol in the same cell where 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 after the end of the last transmitted uplink symbol in the same cell where is given by Table 4.3.2-3.*  We suggest to update the proposal as  **High Priority Proposal 6.1a:**   * For HD-FDD switching time, ~~down-select between the following options in a future meeting, based on RAN4 feedback:~~   + ~~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.~~   + ~~Option 2: Reuse LTE HD-FDD Type-A approach.~~ | |
| FUTUREWEI | Y | |
| CATT | Y, though we prefer Option 1. | |
| OPPO | Y | |
| ZTE | Y | |
| LG | Okay with the proposal. We are not sure yet if the switching time in TS 38.211 can be reused. So, we are not okay with the suggestion from vivo. | |
| Xiaomi | Y | |
| TCL | Y | |
| NEC | Y | |
| CMCC | Y | |
| Lenovo, Motorola Mobility | Fine with FL’s proposal | |
| Samsung | OK with proposal 6.1a | |
| Sharp | Y | |
| China Unicom | Y | |
| Ericsson | We are fine with the proposal. | |
| Huawei, HiSi | Y | |
| **Company** | **Y/N** | **Comments** |
| FL2 |  | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.1a:**   * For HD-FDD switching time, down-select between the following options in a future meeting, based on RAN4 feedback:   + 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.   + Option 2: Reuse LTE HD-FDD Type-A approach. |
| Qualcomm | Y |  |
| FUTUREWEI2 | Y |  |
| Nokia, NSB | Y |  |
| TCL | Y |  |
| Xiaomi | Y |  |
| Ericsson | Y |  |
| vivo | N | Don’t’ want to repeat the earlier comment. Rel-15/16 38.211 spec supports HD-FDD already with switching time clearly defined, and WID says we should minimize the spec impact. Therefore unless there is very strong motivation (so far did not hear any), we should reuse the switching time defined in current spec. |
| Intel | Y | Fine to keep both options open for now, but we do share the same view as Vivo that there should be sufficient justification to motivate Option 2 given that Option 1 is clearly functional and already in specs. |
| LG | Y |  |
| APT | Y |  |
| OPPO | Y | We need to firstly check whether existing switching times for UE not capable of full duplex in TS 38.211 can be applied for Redcap HD-FDD Ues. |
| NEC | Y |  |
| DOCOMO | Y |  |
| China Telecom | Y |  |
| CATT | Y | Still, Option 1 is our 1st preference. |
| Samsung | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Huawei, HiSi | Y |  |
| Spreadtrum |  | Actually, we are not sure we understand these two options correctly.  In our understanding, the difference between option 1 and option 2 is the number of switching times? With option 1, two switching times for DL-to-UL and UL- to-DL are needed, and we can reuse the existing switching times in TS 38.211 . While for option 2, according to the HD-FDD Type-A definition in LTE, only one switching time(guard period) is needed for the DL-to-UL.   |  | | --- | | 36.211:  For type A half-duplex FDD operation, a guard period is created by the UE by  -   not receiving the last part of a downlink subframe immediately preceding an uplink subframe from the same UE. |   Therefore, even for option 2, we can reuse the existing switching time in current spec(38.211) as the guard period.  Is above the common understanding? |
| Lenovo, Motorola Mobility | Y |  |
| CMCC | Y |  |
| InterDigital | Y |  |
| NordicSemi | Y |  |
| MediaTek | Y |  |
| FL3 |  | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.1b:**   * For HD-FDD switching time, based on RAN4 confirmation/feedback:   + If feasible, reuse existing switching times for UE not capable of full duplex in TS 38.211.   + Otherwise, consider defining new symbol-level switching times. |
| FUTUREWEI3 | Y | We are also OK with 6.1a if that has more support than 6.1b. |
| Nokia, NSB |  | Our understanding is that 6.1b discusses only switching times, and we are fine to reuse existing switching times if feasible.  However, we need to also address how the switching is done. In our understanding, if we reuse the current 38.211 specification, there would be impact to both DL and UL slots (at the beginning of the slots). However, if we use LTE Type A HD-FDD definition, there would only be impact to DL slot (at the end of slot). |
| Qualcomm | Y | The switching time in Table 4.3.2-3 of TS 38.211 is the **minimum** gap between UL/DL switching. It applies to TDD operation in NR Rel-15/16 as well.  In terms of implementation, we think a guard period or flexible symbol needs to be introduced to accommodate the switching, similar to NR TDD or LTE Type-A HD-FDD. |
| Intel | Y |  |
| DOCOMO | Y |  |
| Huawei, HiSi | Y |  |
| Xiaomi | Y | Similar consideration with QC |
| LG |  | We agree on the proposal in general. But, even if we can reuse the switching time in TS 38.211, it would be easier if we describe the collision behavior in symbol unit rather than in time unit. So, for the moment we would like to leave room for defining the switching time in symbol units even if we can reuse the switching time in TS 38.211. The following changes are suggested as an example.  **High Priority Proposal 6.1b:**   * For HD-FDD switching time, based on RAN4 confirmation/feedback:   + If feasible, reuse existing switching times for UE not capable of full duplex in TS 38.211.     - FFS whether to define the switching times in symbol units in this case.   Otherwise, consider defining new symbol-level switching times. |
| Vivo |  | It would be necessary if proponents of new switching time can share their understanding what is the feasibility issue to reuse the current 38.211 switching time, and if any reasonable justification can be provided suggest to include such information in the LS so that RAN4 can know the background of the RAN1 discussion . |
| Ericsson | Y |  |
| OPPO | Y | We need to firstly check whether existing switching times for UE not capable of full duplex in TS 38.211 can be applied for Redcap HD-FDD Ues. |
| CATT | Y |  |
| TCL |  | We share similar views as LG. |
| NEC | Y |  |
| Apple | Y | The switching time is typically handled by RAN4 and we are supportive to ask their inputs.  In parallel, RAN1 can discuss whether a symbol-level granularity is defined for Type-A HD-FDD. If we move to symbol-level, a set of values maybe needed for different SCSs. |
| CMCC | Y |  |
| Sharp | Y |  |
| ZTE | Y |  |
| Panasonic | Y |  |
| Samsung | Y |  |
| Spreadtrum | Y | We prefer proposal 6.1b since this proposal is clearer in terms of the description of the difference between two options.  However, we have another concern as mentioned by Nokia that is the switching position. For option 1 in proposal 6.1a, it seems that switching can happen at any symbols in a slot. While for option 2, switching could only happen at the end of a slot. Therefore, we suggest to add a FFS, like :  **High Priority Proposal 6.1b:**   * For HD-FDD switching time, based on RAN4 confirmation/feedback:   + If feasible, reuse existing switching times for UE not capable of full duplex in TS 38.211.   + Otherwise, consider defining new symbol-level switching times.   + FFS: the switching position, e.g. at the end of a slot or at any symbol in a slot or other restriction. |

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. |
| Vivo | Y | The listed 5 cases can be discussed as starting point. |
| Panasonic | Y |  |
| Spreadtrum | Y |  |
| SONY | N | Case 6: monitoring for UL cancellation indication while transmitting in UL.  For FD-FDD, a low priority UL transmission can be cancelled by the gNB sending in a UL cancellation indication in the DL. Some similar functionality should also be supported for HD-FDD.  The 5 listed cases in the FL proposal also need to be considered. |
| ZTE | Y | The listed 5 cases can be as starting point. But not preclude other collision cases if identified. |
| CMCC | Y |  |
| Samsung | Y |  |
| Sharp | Y |  |
| Qualcomm | N | * It is not clear why case 5 excludes RMSI and its scheduling PDCCH. * It is not clear if “configured SSB” refers to cell-defining SSB or not in case 5. * It is not clear whether semi-persistent PUCCH/PUSCH is categorized as “semi-statically configured UL transmission” or “dynamic scheduled UL transmission”. * In directional collision handling, it is good to clarify the content of PUCCH and the priority of PUSCH/PUCCH. |
| Nokia, NSB | Y |  |
| Xiaomi | Y |  |
| Intel | Y |  |
| OPPO | Y |  |
| DOCOMO | Y |  |
| China Telecom | Y |  |
| CATT | Y, almost | We invite companies to check whether ‘Valid PRACH occasion vs. DL reception’ from TDD shall be reused here, which is originally from current TS 38.213 Section 11:  For a set of symbols of a slot corresponding to a valid PRACH occasion and  symbols before the valid PRACH occasion, as described in Sublcause 8.1, the UE does not receive PDCCH, PDSCH, or CSI-RS in the slot if a reception would overlap with any symbol from the set of symbols. The UE does not expect the set of symbols of the slot to be indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*.  …  For a set of symbols of a slot corresponding to a valid PRACH occasion and symbols before the valid PRACH occasion, as described in Clause 8.1, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slotas downlink. |
| LG | N | In our view, they are not complete list to investigate. We share similar view with CATT in that collision with RO should be considered. To comply with the NR spec, the concept of valid RO should be maintained. So, we would like to add a bullet as suggested below.   * Dynamic or semi-static DL vs. RO   In general, as this is the first time we discuss collision issues, it would be hard to make a complete list anyway. Therefore, we would like the proposal to be formulated in a way that it is more accommodating future introduction of any collision issues that are identified in the following meetings. |
| NordicSemi | N | We think that 38.213 sub-clause 11 should be a starting point and we should discuss what should be done differently.  Agree that transmitted SSB and valid RO have special rules in R15/R16 in sub-clause 11, however, for HD-FDD they could be treated as regular semi-static RRC signal. |
| FL4 |  | **Medium Priority Proposal 6-2a:**   * For HD-FDD operation for RedCap Ues, consider at least the following DL/UL collision cases:   + 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   + Case 6: Monitoring for UL cancellation indication while transmitting in UL   + Case 7: Collision due to BWP switching   + Case 8: Dynamic or semi-static DL vs. RO |
| Qualcomm | Partially Y | UE is not expected to receive on DL or transmitted on UL during the gap (guard time) of switching from DL to UL. Therefore, we proposed to add the following case to Proposal 6-2a :  Case 9: Collision due to direction switching |
| Intel |  | We would like to clarify that the proposal does not imply that UE behavior would be defined for all of these cases. In our understanding, many of these can be avoided by proper gNodeB scheduling.  Also, it seems some of these cases can be compressed further at this stage. In this regard, we agree with NordicSemi that Case 8 can be handled under “dynamic or semi-static DL vs. semi-static UL” (Cases 1 and Case 3) without special listing. Similarly, Case 6 should be covered under “semi-static DL reception (PDCCH) vs. dynamic or semi-static UL tx” (Cases 2 and 3).   * For HD-FDD operation for RedCap Ues, consider at least the following DL/UL collision cases:   + 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, or RO   + 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   + ~~Case 6: Monitoring for UL cancellation indication while transmitting in UL~~   + Case 7: Collision due to BWP switching   + ~~Case 8: Dynamic or semi-static DL vs. RO~~ |
| DOCOMO | Y in principle | Cases 6/7 should be FFS as it has not been agreed whether or not RedCap Ues support UL CI or BWP switching |
| Huawei, HiSi |  | Not preferred as we have almost a principle (in FL3) to conditionally use the existing ones as starting point, then only additions need to be handled. But can live the it with similar conditions, i.e. if cannot be up to gNB handling without spec impact, and the Case 9 from Qualcomm can be included in Case7 with modification, thus   * + Case 7: Collision due to BWP switching/RF retuning |
| LG | Y | Okay with the FL4. Also agree with DOCOMO’s suggestion. |
| Vivo |  | We have following questions and comments   1. Is “UL transmission” in case 5 intended to cover both configured UL transmission and dynamic UL transmission, or just one of them, would be good to clarify. 2. Case 6 is already covered by case 3 and case 4, since monitoring for UL cancellation indication is not different from PDCCH monitoring. No need to separate it unnecessarily. 3. What is the relation between the above proposal and **High Priority Proposal 6.3c:** (copied below), we assume for all the cases listed here we will in principle reuse the existing Rel-15/16 handling as the starting point. Maybe it would be good to combine these two proposals for better clarify.   **High Priority Proposal 6.3c:**  For HD-FDD, the existing collision handling principles in Rel-15/16 NR are used as a starting point. |
| OPPO | Y |  |
| CATT | Y, mostly | Also agree with DOCOMO’s view. |
| TCL | Y |  |
| Apple |  | Ok to discuss. Agree with DoCoMo’s points about UL CI. |
| CMCC | Y | Also agree with Intel’s suggestion. |
| Sharp | Y | Same view with DOCOMO. |
| ZTE | Y, mostly | We show similar concern as Intel to clarify that the proposal does not imply that UE behavior would be defined for all of these cases.  For case 8, RO can be regarded as semi-statically configured UL transmission. Therefore, Dynamic vs. RO in Case 8 can be handled in Case 1 and semi-static DL vs. RO can be handled in Case 3.  For case 6/7, we agree with DOCOMO’s suggestion. |
| Panasonic | Y in principle | On case 6 and 7: As pointed out by Docomo, it is not stable whether the RedCap UE supports the UL CI or BWP switching. We propose to make them FFS or clarify like below: o Case 6: Monitoring for UL cancellation indication while transmitting in UL **if UL cancellation is supported by the RedCap UE** o Case 7: Collision due to BWP switching **if BWP switching is supported by the RedCap UE**  On case 5 and 8: We are open whether the special handling on SSB and RO is needed. If case 5 and 8 are kept in the proposal for the sake of progress, we recommend it is clarified that “Semi-statically configured DL” / “Semi-statically configured UL” in the cases 1-4 does not include SSB / RO (PRACH), respectively. |
| Samsung |  | We think it is better to focus on the general case. We don’t think Case 6/7 should be discussed as a separated case here.  For case 8, we are also fine with Intel’s change for case 8.  For Qc’s suggestion, we understand the motivation, however, it is not an additional case, but we should considering the switching time in general during defining the handling of cases. |
| Lenovo, Motorola Mobility | N | We don’t think all cases are necessarily valid. In general, due the flexible scheduling capability in gNB side, some collision might be avoided based on gNB implementation, i.e., the UE will not expect there will be collision happens for some cases, e.g., case 5. |
| Nokia, NSB | Y | We are fine to consider the proposed cases. |
| NordicSemi | Y, but | Fine to list cases, but we not sure this is the right approach. It would be better to discuss companies proposals about what they want to change compared to R15/R16. 😊 |
| InterDigital | Y |  |

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. |
| China Telecom | N | In RedCap WID, for Duplex operation:   * HD-FDD type A with the minimum specification impact (Note that FD-FDD and TDD are also supported.)   Hence, we don’t expect other additional specification impacts from HD-FDD Type-A for RedCap UEs. |
| Intel | N | Same view as Ericsson and Nokia on TDD configurations. The existing NR specs are already capable enough to address HD-FDD Ues in the most flexible way. Some further handling may be defined for a few overlapping/conflict cases following existing specs, and should be limited to the scope mentioned the question. |
| CATT | N | Semi-static TDD-like pattern puts restriction on scheduling flexibility and increases the network complexity. DL/UL collision can be handled well without such configuration. |
| Sharp | N | Same view as Ericsson, Nokia and Intel. Further handling may not be necessary. |
| Vivo | N | For collision handling, we think current rule defined in TS 38.213 section 11.1 on collision handling can be used as baseline. |
| Huawei | N | The objective in WID is *HD-FDD type A with the minimum specification impact* |
| Xiaomi | Y | Similar as QC, we think it is necessary to allow gNB to configure at least DL or UL slot/symbols for Redcap Ues. |
| Samsung | N | We think collision handling rule should be enough. No need to introduce semi-static UL/DL direction. |
| Panasonic | N |  |
| Spreadtrum | N |  |
| LG | N | Configuring semi-static TDD-like slot format to support HD-FDD in FDD bands puts unnecessary restrictions to gNB scheduling flexibility. HD-FDD in FDD bands can be supported by gNB scheduling without TDD-like slot format configuration. For the collision cases that can still happen, the solution should be based on the existing rule if any. If there are collision cases that are not covered by existing rules, specification work may be needed. |
| OPPO | N |  |
| InterDigital | N |  |
| Lenovo, Motorola Mobility | N |  |
| FUTUREWEI | N | Initial access times may need some checking |
| SONY | N | We assume there are 6 collision cases (see answer to question 6-2) |
| APT | Y | We may consider configuring a semi-static TDD-like slot format configuration for HD-FDD operation to avoid frequent collision handling, otherwise the collision handling should be clearly defined and may also have some specification impact. |
| Apple | N | In our view, scheduling flexibility is also important for Redcap device as indicated by the required latency performance for some target devices and solution causing latency increase should be carefully justified. |
| FL1 | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.3a:**   * For HD-FDD:   + FFS: need for semi-static TDD-like slot format configuration | |
| Qualcomm | We are ok with FL1 proposal as above. In our opinion, re-using the solutions of directional collision available to NR TDD can minimize the standardization efforts for NR Rel-17 RedCap devices, and does not contradict with the existing rules for collision handling specified in NR Rel-15/16. | |
| InterDigital | Y | |
| Intel | Y | |
| DOCOMO | We are fine with FL1 proposal | |
| Nokia, NSB | No. We do not think the reasons provided in the responses justify further study of semi-static TDD-like configuration. It clearly has larger specification impact than defining collision handling rules, introduces significant implementation complexity and restriction, and does not really result in UE power saving in our view. | |
| Vivo | WID says we should minimize the spec impact. The FFS bullet is an optimization, not must to have. We prefer to remove it. | |
| CATT | We don’t think semi-static TDD-like slot format configuration is needed. | |
| OPPO | If the current collision handling is enough, no need for semi-static TDD-like slot format configuration to minimize the specification impact. | |
| ZTE | Further study on semi-static TDD-like slot format configuration is not precluded | |
| LG | We don’t have a strong view to further consider the semi-static TDD-like slot format configuration, but we have a similar view with Nokia in that it is unnecessary restrictions to gNB scheduling flexibility. | |
| Xiaomi | Same view with QC | |
| TCL | Y | |
| NEC | Y | |
| CMCC | Y | |
| Lenovo, Motorola Mobility | Fine with FL’s proposal | |
| Samsung | We don’t think this proposal is needed.  We suggest to agree some general principle other than agree an FFS. Such as:   * For HD-FDD, current collision handling principle is a starting point, such as, dynamic scheduling overwrites semi-statically configurations.   And question 6-2 can be a good starting point by listing all the cases need to be revisited. | |
| Sharp | Y | |
| China Unicom | Y | |
| Ericsson | We do not see benefit of adopting semi-static TDD-like slot format configuration for HD-FDD UEs, and we are very concerned with scheduling flexibility and impact on UE throughput. However, since this is the very first RAN1 meeting for the RedCap WI, we can be okay with FFS. We would like to suggest adding scheduling flexibility and impact on UE throughput considerations to the FFS.   * For HD-FDD:   + FFS: need for semi-static TDD-like slot format configuration. Scheduling flexibility and impact on UE throughput should be considered. | |
| Huawei, HiSi | Agree with Nokia | |
| **Company** | **Y/N** | **Comments** |
| FL2 |  | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.3b:**   * For HD-FDD, the existing collision handling principles in Rel-15/16 NR are used as a starting point, e.g. that dynamically scheduled transmission overrides semi-statically configured transmission.   + FFS: need for semi-static TDD-like slot format configuration. Scheduling flexibility and impact on UE throughput should be considered in the analysis. |
| Qualcomm | Y | * For semi-static, TDD-like slot format configuration, the DL/flexible/UL slot/symbol configuration can be based on SI and/or dedicated RRC signaling. * Guard period required by DL/UL switching can be accommodated by the flexible symbol, which is already supported by TDD slot configuration. It is not necessary to introduce another guard period to meet the requirements for HD-FDD switching. * Procedures specified in Clause 11.1, TS 38.213 can be re-used by RedCap UE not supporting simultaneous transmission and reception. |
| FUTUREWEI2 |  | The FFS seems pretty clearly out of scope of the WID. We can accept if everyone else does. Otherwise we suggest to agree on the main bullet is enough, supporters of the FFS can prove the need to go beyond the starting point without the explicit FFS. |
| Nokia, NSB |  | We are fine with the main bullet. We do not think the FFS is necessary and would like to remove it as we understand that once the collision handling is defined there is no longer clear benefit to support TDD-like slot format configuration. |
| TCL | Y |  |
| Xiaomi | Y | As for the FFS part, we think the TDD-like slot format configuration is one effective to avoid collision with less complexity on the scheduler. Furthermore, such mechanism was already supported in NR, reusing it would cause little standardization effort. Therefore, we think the FFS part should be kept. |
| Ericsson | Y |  |
| vivo |  | We prefer to remove the FFS, same reason as commented before by many companies. But we won’t object to keep the FFS is there is majority of companies support it. |
| Intel |  | While we would not object to the proposal, we sympathize with Futurewei and Nokia’s comments on the FFS bullet. Thus, we would also be supportive to remove the FFS bullet on semi-static TDD configuration since the benefits are still not clear.  As long as there will be flexible symbols, and the likely outcome that semi-static configuration will be optional for the gNB even if supported by specs, we do not see any benefits to UE complexity or specification work since UE behavior and collision handling (which is not significant in our understanding in the first place) would need to be defined in any case. |
| LG |  | Same view with Nokia. Okay with the main bullet and prefer to remove the FFS.  Without changing the current spec, if TDD-like slot format is not configured the slot format is treated like flexible as I understand it. Then the guard period can also be accommodated by the flexible anyway without TDD-like slot format. With the collision handling with the legacy rule as a starting point as the main bullet says, HD-FDD can be supported without TDD-like slot format without restrictions on the scheduling flexibility. |
| APT | Y | We prefer to keep the FFS. |
| OPPO |  | Before we clearly have a understanding whether there is a gap with the existing collision handling principles in Rel-15/16 NR, we prefer to remove the FFS since it is more like one optimization method. |
| DOCOMO | Y | At least main bullet should be agreed. We don’t see the necessity of FFS bullet but don’t object to keep it for the sake of progress |
| China Telecom | Y | We are fine to use the existing collision handling principles in Rel-15/16 NR as a starting point. Whether FFS is needed, it would be better to double check after more discussion and better understanding on the existing collision handling principles in Rel-15/16 NR. |
| CATT |  | Prefer no FFS part, which is not essential at all and against the principle that the specification impact should be minimized. The existing collision handling principle is quite sufficient to support HD-FDD. |
| Samsung | Y | We are OK to leave a FFS for this meeting although we don’t see the need for TDD-like semi-static configuration. |
| Sharp | Y | We are OK with the current FL proposal though FFS part can be removed. |
| ZTE |  | Collision handling procedure specified in Clause 11.1 of TS 38.213 can be taken as a starting point for collision handling for RedCap UEs. In the main bullet, we prefer to remove “e.g. that dynamically scheduled transmission overrides semi-statically configured transmission”.  Regarding the FFS part, considering that semi-static TDD-like slot format configuration may be reused for RedCap UEs with minor standardization effort, our preference is to keep the FSS part. |
| Huawei, HiSi | N | We prefer the original proposal in FL1. |
| Spreadtrum |  | We are OK with the main bullet.  Regarding the FFS, we don’t see any necessity to keep it here at this stage, since we need focus on the existing collision handling principles, if the existing principles cannot work well, then other solution can be considered later. So we prefer to remove the FFS. |
| Lenovo, Motorola Mobility | Y | We are fine with the main bullet. We don’t think the FFS is necessary but fine to keep it for now. |
| CMCC | Y |  |
| InterDigital | Y | We do not see the necessity of the FFS. |
| NordicSemi | Y | Since this is first WID meeting, FFS is OK to keep. Also we could be more concrete that existing collision handling principles are those in 38.213 sub-clause 11 ? |
| MediaTek | Y | We are fine with removing the FFS point as suggested by other companies. |
| FL3 |  | Based on the received responses, the following proposal can be considered.  **High Priority Proposal 6.3c:**   * For HD-FDD, the existing collision handling principles in Rel-15/16 NR are used as a starting point. |
| FUTUREWEI3 | Y |  |
| Nokia, NSB | Y |  |
| Qualcomm |  | The FL3 proposal is too broad for RedCap UE because:   * The existing collision handling principles in Rel-15/16 NR include DC/CA operation, which are unnecessary for R17 RedCap UEs. * DCI format 2\_0 (SFI) detection is an optional feature for Rel-15/16 UE operating on paired/unpaired spectrum * DCI format 2\_4 (ULCI) detection is an optional feature for R16 UE, which requires Cap#2 for N2   We also noted most of the collision handling rules cited by companies (e.g. Vivo) are based on Clause 11.1 of TS 38.213, and the rules are specified for UE operation on a single carrier in unpaired spectrum.  For Rel-15/16 UE operating on a single carrier in unpaired spectrum, if it is not configured with a semi-static slot format by higher layer or is not required to monitor dynamic SFI in DCI 2\_0, it will follow dynamic grant and other rules in Clause 11 of TS 38.213.  So far, most companies agree that the minimum switching time between TX/RX for a HD-FDD UE is no different from the R15/16 UE incapable of simultaneous transmission and reception on the same carrier (i.e. single carrier in unpaired spectrum ) or different carriers (e.g. ENDC, CA), as specified by Table 4.3.2-3 of TS 38.211.  As a compromise, we suggest the following revision for FL3 proposal and hope it can be agreed by other companies:  ***Proposal 6.3C\_rev:***  ***• For HD-FDD, the existing collision handling principles in Rel-15/16 NR for operation on a single carrier in unpaired spectrum are used as a starting point.*** |
| Intel | Y | We are fine with the high-level description in FL3. However, we are not sure about the suggested update from Qualcomm as it may imply that we would be agreeing to have *all components* currently available for operation in TDD for HD-FDD. |
| DOCOMO | Y |  |
| Huawei, HiSi | Y with modifications | Prefer FL1 but can live with the FL3 with modifications. The addition proposed from Qualcomm is not our preference.   * For HD-FDD, the existing collision handling principles in Rel-15/16 NR can be ~~are~~ used as a starting point, if cannot be up to gNB handling (i.e. no specific spec impact). |
| Xiaomi |  | We are OK with QC’s revision |
| LG | Y | Also, not against the QC’s proposal, but we are not sure yet whether the collision handling ***for operation on a single carrier in unpaired spectrum*** covers all the cases for HD-FDD to work in FDD bands. So, the version tagged FL3 is preferred. |
| Vivo |  | We think the proposed revision by Qualcomm above provides more clarity, we support it. |
| Ericsson | Y |  |
| OPPO | Y | We agree that Qualcomm’s revision is more clear. |
| CATT | Y | Since RedCap UE is not expected to have over-design capabilities such as CA/DC, it is natural to consider only single carrier case (at least as the starting point), with or without explicit precluding other cases. |
| TCL | Y | Fine with QC’s revision. |
| NEC | Y |  |
| Apple | Y |  |
| CMCC | Y | Fine with QC’s revision. |
| Sharp | Y |  |
| ZTE |  | We are fine with Qualcomm’s modification. |
| Panasonic | Y |  |
| Samsung | Y | Fine with Qc’s modification. |
| Lenovo, Motorola Mobility | Y |  |
| NordicSemi | Y | QC version is more accurate. |

# 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 |
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| [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 |
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| [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 |
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| [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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