3GPP TSG-RAN WG1 Meeting #105-e R1-21xxxxx

e-Meeting, 19th – 27th May 2021

**Agenda Item: 8.6.1.1**

**Title: FL summary #1 on reduced maximum UE bandwidth for RedCap**

**Source: Moderator (Ericsson)**

**Document for: Discussion, Decision**

# Introduction

This feature lead (FL) summary (FLS) concerns the Rel-17 work item (WI) for support of reduced capability (RedCap) NR devices [1]. Earlier RAN1 agreements for this WI are summarized in [2].

This document summarizes contributions [3] – [31] submitted to agenda item 8.6.1.1 and relevant parts of contributions [32] – [34] submitted to agenda item 8.6.3 and captures this email discussion on reduced maximum UE bandwidth:

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| [105-e-NR-R17-RedCap-01] Email discussion regarding aspects related to reduced maximum UE bandwidth – Johan (Ericsson)* 1st check point: 5/21
* 2nd check point: 5/25
* Final check: 5/27
 |

The final FLS from the previous RAN1 meeting and the draft LS that was discussed then can be found in [35] and [36].

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

1. High Priority
2. Medium Priority

In this round of the discussion, companies are requested to provide comments on the proposals and questions tagged FL1.

Follow the naming convention in this example:

* *RedCapBwFLS1-v000.docx*
* *RedCapBwFLS1-v001-CompanyA.docx*
* *RedCapBwFLS1-v002-CompanyA-CompanyB.docx*
* *RedCapBwFLS1-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 *RedCapBwFLS1-v002-CompanyA-CompanyB.docx*.
* CompanyC uploads an empty file named *RedCapBwFLS1-v003-CompanyB-CompanyC.checkout*
* CompanyC then has 30 minutes to upload *RedCapBwFLS1-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 the underline character) and include ‘v’ in front of the version number, as in the examples above and in line with the general recommendation (see slide 10 in [R1-2104152](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104152.zip)), otherwise the sorting of the files will be messed up (which can only be fixed by the RAN1 secretary).

To avoid excessive email load on the RAN1 email reflector, please note that there is NO need to send an info email to the reflector just to inform that you have uploaded a new version of this document.

# Initial DL BWP

## Initial DL BWP during initial access

RAN1#104bis-e agreed the following working assumption related to initial DL BWP during initial access:

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| Working assumption:* During initial access, the bandwidth of the initial DL BWP for RedCap UEs is not expected to exceed the maximum RedCap UE bandwidth.
	+ The bandwidth and location of the initial DL BWP for RedCap UEs can be the same as the bandwidth and location of the MIB-configured initial DL BWP for non-RedCap UEs.
	+ This does not preclude a SIB-configured initial DL BWP for non-RedCap UEs only with a wider bandwidth than the maximum RedCap UE bandwidth.
	+ This does not preclude separate or additional bandwidth and location for initial DL BWP for RedCap UEs (FFS).
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Regarding the initial DL BWP, contributions unanimously agree to confirm the working assumption indicating that, during initial access, the bandwidth of the initial DL BWP for RedCap UEs is not expected to exceed the maximum RedCap UE bandwidth [3, 4, 6, 7, 9, 10, 13, 14, 17, 18, 19, 21, 22, 26]. However, one contribution [31] discusses that a RedCap UE can be configured with a BWP larger than its maximum supported bandwidth.

**FL1 High Priority Proposal 2.1-1: Confirm the following RAN1#104bis-e working assumption:**

* **During initial access, the bandwidth of the initial DL BWP for RedCap UEs is not expected to exceed the maximum RedCap UE bandwidth.**
	+ **The bandwidth and location of the initial DL BWP for RedCap UEs can be the same as the bandwidth and location of the MIB-configured initial DL BWP for non-RedCap UEs.**
	+ **This does not preclude a SIB-configured initial DL BWP for non-RedCap UEs only with a wider bandwidth than the maximum RedCap UE bandwidth.**
	+ **This does not preclude separate or additional bandwidth and location for initial DL BWP for RedCap UEs (FFS).**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y |  |
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Regarding the FFS for whether a separate or additional bandwidth and location for initial DL BWP for RedCap UEs, most of the contributions state that the possibility of configuring such separate initial DL BWP can be beneficial in terms of e.g. flexibility and offloading purposes [3, 10, 16, 18, 19, 20, 21, 22, 24, 25, 26, 30]. One contribution [8] argues that separate/additional bandwidth and location for initial DL BWP for RedCap UEs should not be considered in Rel-17 because it occupies additional DL resources and there is no issue with using the same initial DL BWP for RedCap and non-RedCap UEs.

The following proposal concerns initial DL BWP use during initial access. A related proposal regarding use after initial access is included in Section 2.2.

**FL1 High Priority Proposal 2.1-2:**

* **An initial DL BWP for RedCap UEs for use during initial access can be configured separately from the initial DL BWP for non-RedCap UEs.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Conditioned Y  | The same CORESET#0 is assumed and additional other CORESETs are to be further discussed. |
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## Initial DL BWP after initial access

RAN1#104bis-e agreed the following working assumption related to initial DL BWP after initial access:

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| Working assumption: * After initial access, at least for BWP#0 configuration option 1 (as in 38.331, Appendix B2), a RedCap UE is not expected to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth.
	+ FFS: BWP#0 configuration option 2 (as in 38.331, Appendix B2)
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One of the working assumptions indicated in RAN1#104bis-e is that after initial access, at least for BWP#0 configuration option 1 (as in 38.331, Appendix B2), a RedCap UE is not expected to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth and it is FFS whether this applies to BWP#0 configuration option 2 (as in 38.331, Appendix B2).

Most of the contributions, e.g. [3, 5, 6, 7, 8, 9, 12, 13, 14, 16, 18, 20], agree to confirm this working assumption. Also, regarding the FFS, they indicate that, similar to the case for BWP#0 configuration option 1, a RedCap UE is not expected to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth for BWP#0 configuration option 2. One contribution [4] mentions that further clarification on BWP#0 configuration is needed, especially regarding the term “after initial access”.

**FL1 High Priority Proposal 2.2-1: Replace the RAN1#104bis-e working assumption with the following agreement:**

* **After initial access (i.e., after RRC Setup, RRC Resume, or RRC Reestablishment), for both BWP#0 configuration options 1 and 2 (as in 38.331, Appendix B2), a RedCap UE is not expected to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y |  |
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The following proposal is related to a corresponding proposal in Section 2.1.

**FL1 High Priority Proposal 2.2-2:**

* **If an initial DL BWP for RedCap UEs** **for use during initial access is configured separately from the initial DL BWP for non-RedCap UEs, this separately configured initial DL BWP for RedCap UEs can also be used after initial access (i.e., after RRC Setup, RRC Resume, or RRC Reestablishment).**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y |  |
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## Additional CORESET for Msg2/Msg4/Paging/SI

Another FFS (identified in RAN1#104-e) is whether an additional CORESET can be configured for RedCap for the purpose of offloading Msg2/Msg4/Paging/SI messages.

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| Agreements:* 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.
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There are different views on introducing an additional CORESET for offloading purposes. Several contributions [3, 12, 16, 20, 21, 25] state that having additional CORESET for scheduling of Msg2/Msg4/Paging messages (and perhaps but not necessarily for SI messages) can be beneficial for congestion mitigation and offloading purposes. Meanwhile, a few other contributions [5, 8, 9] argue that an additional CORESET is not needed in Rel-17 since the congestion is not expected to be significant. One contribution [6] states that a separate initial DL BWP for RedCap UE is preferred and that it is not necessary to support the additional CORESET that is within the initial DL BWP shared between the RedCap and non-RedCap UEs.

**FL1 High Priority Question 2.3-1:**

* **Should the possibility to configure an additional CORESET for scheduling of Msg2 and/or Msg4 and/or Paging and/or SI for RedCap UEs be supported? Please provide a motivation for your answer.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi |  | Traffic load for the initial commercialization of RedCap might not be significant as one aspect. Additionally there could be the potential impact at gNB side in the above case in order to support multiple CSS of same type. We are not in favour of this approach. |
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In addition, there are a few more detailed proposals related to the additional CORESET, if introduced:

* Contributions [3, 20] argue that in the frequency domain, the additional CORESET should be non-overlapping (partially or fully) with CORESET #0.
* Contribution [3] suggests that the additional CORESET can be defined within the RedCap initial DL BWP and used for offloading Msg2, Msg4, paging and SI (other than SIB1) message transmissions, while CORESET #0 is used for scheduling SIB1.
* Contribution [16] comments that an additional CORESET can be beneficial for offloading paging and/or random access for RedCap UEs, but since the same SI messages are expected to be shared between RedCap and non-RedCap UEs, it may not be as beneficial to offload SI messages (RMSI, OSI) to an additional BWP.

**Medium Priority Question 2.3-2:**

* **In case RAN1 would introduce a possibility to configure an additional CORESET for offloading purposes for RedCap UEs, what are your views on the following aspects?**
1. **The position/configuration of such new CORESET**
2. **The messages/transmissions which can or cannot be offloaded on this CORESET**

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| **Company** | **Comments** |
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# Initial UL BWP

## General

RAN1#104bis-e made the following agreements related to initial UL BWP [2]:

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| Agreements:* During initial access, for the scenario where the initial UL BWP for non-RedCap UEs is configured to be wider than the RedCap UE bandwidth, down select among the following options in RAN1#105-e
	+ Option 1: The scenario is allowed, and a RedCap UE can use the same UL BWP.
	+ Option 2: The scenario is allowed, but a separate initial UL BWP no wider than the RedCap UE maximum bandwidth is configured/defined for RedCap UEs.
	+ Option 3: The scenario is not allowed, and a RedCap UE is not expected to operate in an initial UL BWP wider than the RedCap UE maximum bandwidth.

Agreements:* After initial access, for the scenario where the initial UL BWP for non-RedCap UEs is configured to be wider than the RedCap UE bandwidth, down select among the following options in RAN1#105-e:
	+ Option 1: The scenario is allowed, and a RedCap UE can use the same UL BWP.
	+ Option 2: The scenario is allowed, but a separate initial UL BWP no wider than the RedCap UE maximum bandwidth is configured/defined for RedCap UEs.
	+ Option 3: The scenario is not allowed, and a RedCap UE is not expected to operate in an initial UL BWP wider than the RedCap UE maximum bandwidth.
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Almost all contributions listed in the references discuss the options of initial UL BWP according to the above-mentioned agreements. In the consideration of preferred or acceptable options, all the sources also consider the related issues of RACH occasions and PUCCH/PUSCH transmissions during initial access.

Many contributions identify important issues and foreseeable impacts concerning each of these options. These aspects can be further considered.

**Option 1: The scenario is allowed, and a RedCap UE can use the same UL BWP**

* Specification impact (e.g. RF-retuning delay, PUCCH/Msg3 design, allowing configuring a BWP wider than the UE BW) [3, 4, 8, 9, 20, 22, 24, 27]
* Negative impact on UE power consumption and/or complexity [9, 11, 12, 13, 24, 25]
* Reduce the demodulation performance of PUCCH and/or PUSCH [10, 18]
* Introducing complexity at the network [9]
* Reduced throughput due to BWP switching delay [29]
* Early identification is desired to avoid multiplexing RedCap UEs and non-RedCap UEs on the same [10]
* UL resource wastage due to RF retuning [16]
* The feasibility and the impact on the UL/DL switching time should be studied if the centre frequency of the UL resource is different from the centre frequency of DL BWP [22]
* Scheduling of Msg1/Msg2/Msg3/Msg4 needs to take into account the delay necessary for RF retuning [27]

**Option 2: The scenario is allowed, but a separate initial UL BWP no wider than the RedCap UE maximum bandwidth is configured/defined for RedCap UEs**

* PUSCH resoure fragmentation [3, 20, 24, 27, 32]
* May lead to signaling overhead in SIB1. New SIB information is needed [17, 20, 24]
* Some resource utilization efficiency loss since normal UE and RedCap devices may not share certain channels or resources [22]
* PRACH resource fragmentation due to a rigid split between RedCap and non-RedCap resources [27]
* Should avoid specifying multiple initial UL BWPs for RedCap UE and allowing BWP switching during initial access will increase the signaling overhead of NW, complexity of UE, and the spec impacts of RAN1/RAN2/RAN4 [11]

**Option 3: The scenario is not allowed, and a RedCap UE is not expected to operate in an initial UL BWP wider than the RedCap UE maximum bandwidth**

* Too restricted with reduced flexibility on the network, which might lead to negative impact on non-RedCap UEs [3, 6, 8, 10, 12, 13, 14, 20, 22, 24, 25, 27, 29]
* PUSCH resource fragmentation [3, 32]
* The performance of RedCap UEs may be impacted [29]

When all the aspects are considered, the proposals from the submitted contributions are summarized as follows.

* A majority of the contributions prefer Option 2 for both during and after initial access [5, 6, 7, 8, 10, 12, 13, 14, 17, 18, 19, 21, 22, 23, 24, 25, 28, 29].
* Contribution [8] prefers Option 2 but can also accept Option 1.
* Contributions [3, 20, 27, 32] consider both Options 1 and 2 for further discussion.
* Contribution [31] prefers Option 1.
* Contributions [9, 16] prefer Option 3 but can also accept Option 2.
* Contribution [4] proposes to down select between Options 2 and 3.

As summarized above, among the contributions that prefer or include Option 3, most can also accept Option 2. Furthermore, many contributions express concerns with the impact on non-RedCap UEs from Option 3 [3, 6, 8, 10, 12, 13, 14, 20, 22, 24, 25, 27, 29]. Thus, it seems that it might be possible to agree to the FL proposal below.

**FL1 High Priority Proposal 3.1-1:**

* **Both during and after initial access, the scenario where the initial UL BWP for non-RedCap UEs is configured to be wider than the RedCap UE bandwidth is allowed.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y |  |
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Furthermore, considering the strong support for Option 2, a possible way forward is to consider agreeing to Option 2 as a working assumption and aim to address the main issues identified for Option 2. To that end, many contributions identify the problem of PUSCH resource fragmentation [3, 5, 24, 26, 27, 32], and contributions [3, 5, 16, 32] consider the following possible solutions:

* The narrower initial UL BWP for RedCap UE may be configured at an edge of the UL carrier, thereby minimizing impact from UL resource fragmentation. [3, 16, 32]
* RF retuning may occur between uplink transmission and downlink reception in TDD for RedCap UEs. [3, 5, 32]
* Disable frequency hopping for Msg4 PUCCH. [3, 32]
* A RedCap BWP can be configured with multiple locations (start PRB). [5]
	+ BWP retuning occurs among different locations (start PRB).
	+ A RedCap BWP can be configured with multiple locations (start PRB). BWP retuning occurs among different locations associated to the same RedCap BWP (index).

**FL1 High Priority Proposal 3.1-2:**

* **Working assumption: Both during and after initial access, for the scenario where the initial UL BWP for non-RedCap UEs is configured to be wider than the RedCap UE bandwidth, a separate initial UL BWP no wider than the RedCap UE maximum bandwidth is configured/defined for RedCap UEs.**
	+ **The specifications shall ensure coexistence with non-RedCap UEs (e.g. avoiding or minimizing PUSCH resource fragmentation), if a separate initial UL BWP for RedCap UEs is configured.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y and | “**coexistence with non-RedCap UEs**” is already in the WID. We think a step forward could be:* + **~~The specifications shall ensure coexistence with non-RedCap UEs (e.g. avoiding or minimizing PUSCH resource fragmentation), if a separate initial UL BWP for RedCap UEs is configured,~~ Strive for a mean to avoid or minimize the PUSCH resource fragmentation for the above case.**
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Another FFS (identified in RAN1#104-e) is 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

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| Agreements:* 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.
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Contribution [16] proposes that a separate initial UL BWP for RedCap can be considered even if the bandwidth of the initial UL BWP for non-RedCap does not exceed the maximum RedCap UE bandwidth.

**Medium Priority Question 3.2-3:**

* **Should configuration of a SIB-configured initial UL BWP for RedCap UEs different from the SIB-configured initial UL BWP for non-RedCap UEs be supported even in case the bandwidth of the initial UL BWP for non-RedCap does not exceed the maximum RedCap UE bandwidth?**

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| **Company** | **Y/N** | **Comments** |
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## RACH occasions

RAN1#104-e made the following agreements related to RACH occasions:

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| Agreements:* Study further how to enable/support that a RACH occasion associated with the best SSB falls within the RedCap UE bandwidth, with the following options:
	+ Option 1: Proper RF-retuning for RedCap
* Option 2: Separate initial UL BWP(s) for RedCap UEs
* Option 3: gNB configuration (e.g., restrictions on existing PRACH configurations, or FDM-ed ROs, or always restricting the initial UL BWP to within RedCap UE bandwidth)
* Option 4: Dedicated PRACH configurations (e.g., ROs) for RedCap UEs
* Other options are not precluded
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Many contributions listed in the references discuss the options listed in the above-mentioned agreement. Many contributions identify important issues and foreseeable impacts concerning each of these options. A summary is given below. Additionally, many of the issues summarized in Section 3.1 are also relevant and should also be considered.

**Option 1: Proper RF-retuning for RedCap**

* Need longer time between PRACH and RAR (Msg2) [3, 13, 21, 26]
* Negative impact on UE power consumption and complexity [11, 12]
* For TDD operation, it would be needed that the centre frequency between DL and UL BWP is different. It requires the discussion whether it is allowed for the RedCap [25]
* Need different interpretation of PRACH transmission or adjustment of initial UL BWP [26]

**Option 2: Separate initial UL BWP(s) for RedCap UEs**

* Resource fragmentation [3, 8, 32]
* SIB1 related issues such as need additional indication (either implicitly or explicitly), heavier payload in SIB1, higher overhead, and specs impact [3, 8, 25, 26]
* Whether there is one common initial UL BWP for all RedCap UEs or multiple ones [13, 21]
* The initial UL BWP and the initial DL BWP may have different central frequencies for TDD [3, 13, 26, 32]
* Whether dedicated PRACH configurations (e.g., ROs) for RedCap UEs can be configured [21, 28]
* Increased gNB processing for PRACH [3]
* Maintenance of two different initial UL BWPs [8]

**Option 3: gNB configuration (e.g., restrictions on existing PRACH configurations, or FDM-ed ROs, or always restricting the initial UL BWP to within RedCap UE bandwidth)**

* Negative impact on the non-RedCap UE. May increase random access collision [5, 7, 8, 12, 13, 26, 28]

**Option 4: Dedicated PRACH configurations (e.g., ROs) for RedCap UEs**

* This option consumes additional uplink resources and the resource utilization efficiency may degrade since Redcap UE and legacy UE cannot share the same PRACH resources. For popular TDD configuration such as DDDSU, this additional cost is non-negligible [8, 13]
* Cannot fully resolve the issue [5]
* Less flexible than Option 2 [7]
* May complicate gNB’s resource allocation [3, 13]
* Increase the overhead and gNB PRACH processing load [3]
* gNB would always configure dedicated ROs even for a very small number of RedCap UEs [3]
* Need additional indication (either implicitly or explicitly) [26]
* Separate PRACH configurations for RedCap UEs can be supported by specification regardless whether where the bandwidth of initial UL BWP for non-RedCap UEs is no wider than the maximum RedCap UE bandwidth [21]

In addition to the above 4 options, two new options are mentioned.

* Separate initial UL BWP with multiple locations (start PRB) for RedCap UEs can well enable/support that a RACH occasion associated with the best SSB falls within the RedCap UE bandwidth [5]
* Whether the associated RO is within the UE bandwidth is a consideration for SSB selection. Whether the associated RO is within the UE bandwidth is a consideration for RO selection [15]

Considering these options are coupled with the options for the initial UL BWP, the FL suggests we come back to the down-selection of these options after the down-selection of the options for the initial UL BWP.

## PUCCH/PUSCH during initial access

RAN1#104-e made the following agreements related to PUCCH/PUSCH during initial access:

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| Agreements:* Study further whether and how to enable/support that PUCCH (for Msg4/[MsgB] HARQ feedback) and/or PUSCH (for Msg3/[MsgA]) transmissions fall within the RedCap UE bandwidth during initial access, with the following options:
	+ Option 1: Proper RF-retuning for RedCap (if feasible)
	+ Option 2: Separate initial UL BWP(s) for RedCap
		- FFS more than one starting PRB position
	+ Option 3: Separate PUCCH/Msg3/[MsgA] PUSCH configuration/indication or a different interpretation for the same configuration/indication for RedCap (e.g., disabled frequency hopping or different frequency hopping)
	+ Option 4: gNB configuration (e.g., always restricting the initial UL BWP to within RedCap UE bandwidth, or restrictions on the frequency location and the amount of scheduled resource for Msg4/[MsgB] HARQ feedback and Msg3/[MsgA] PUSCH)
		- As an example, with restrictions on the frequency location and the amount of scheduled resource for Msg4/[MsgB] HARQ feedback and Msg3/[MsgA] PUSCH, when the initial UL BWP is the same for RedCap and non-RedCap UEs, the PUCCH (for Msg4/[MsgB] HARQ feedback) and PUSCH (for Msg3/[MsgA]) are within the RedCap UE bandwidth
	+ Other options are not precluded
 |

Many contributions listed in the references discuss the options listed in the above-mentioned agreement. Many contributions identify important issues and foreseeable impacts concerning each of these options. A summary is given below.

**Option 1: Proper RF-retuning for RedCap (if feasible)**

* Impact on frequency hopping. May need longer time between 1st and 2nd hops, or may not be feasible [22, 26, 28]
* Reduce the demodulation performance of PUSCH [10, 22]
* Performance loss for PUCCH, especially for short duration PUCCH. PUCCH enhancements need to be introduced for RedCap UEs [3, 8, 10]
* Negative impact on UE power consumption and complexity [11, 12]
* The number of occasions of RF retuning is too large [7]
* Early identification is desirable [10]
* Need clarification regarding whether the fast frequency retuning capability is a reasonable assumption for (all) the RedCap UEs [21]
* Issues foreseen when the RedCap UEs have to perform frequency hopping between two hops within a slot [21]
* For TDD operation, it would be needed that the centre frequency between DL and UL BWP is different. It requires the discussion whether it is allowed for the RedCap [25]

**Option 2: Separate initial UL BWP(s) for RedCap**

* Resource fragmentation [3, 21, 26, 32]
* SIB1 related issues such as need additional indication (either implicitly or explicitly), heavier payload in SIB1, higher overhead, and specs impact [8, 25, 26]
* May require different center frequencies for initial UL BWP and DL BWP in TDD [3, 32]
* Maintenance of two different initial UL BWPs [8]

**Option 3: Separate PUCCH/Msg3/[MsgA] PUSCH configuration/indication or a different interpretation for the same configuration/indication for RedCap (e.g., disabled frequency hopping or different frequency hopping)**

* Less flexible than Option 2 [7]
* For PUCCH for Msg4, different configuration/indication/interpretation is needed [8]
* Early identification is needed [10]
* Specification impact [10, 12]
* Need additional indication (either implicit or explicit) [26]
* Fragmentation of PUSCH resources for non-RedCap UEs [26]
* A new hopping pattern for RedCap UEs may be defined [28]

**Option 4: gNB configuration (e.g., always restricting the initial UL BWP to within RedCap UE bandwidth, or restrictions on the frequency location and the amount of scheduled resource for Msg4/[MsgB] HARQ feedback and Msg3/[MsgA] PUSCH)**

* Negative impact on the non-RedCap UEs. Limited configuration for non-RedCap UEs [7, 8, 12, 26, 28]
* PUSCH resource fragmentation [3, 5, 32]
* Decrease network capacity [5]

Considering these options are coupled with the options for the initial UL BWP, the FL suggests we come back to the down-selection of these options after the down-selection of the options for the initial UL BWP.

# Non-initial BWP

For non-initial BWP operation, we have the following working assumption based on RAN1#104bis-e:

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| Working assumption: * A RedCap UE cannot be configured with a non-initial (DL or UL) BWP (i.e., a BWP with a non-zero index) wider than the maximum bandwidth of the RedCap UE.
	+ At least for FR1, FG 6-1 ("Basic BWP operation with restriction" as described in TR 38.822) is used as a starting point for the RedCap UE type capability.
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Contributions generally agree with the main bullet in the working assumption stating that a RedCap UE cannot be configured with a non-initial (DL or UL) BWP wider than the maximum bandwidth of the RedCap UE [3, 4, 5, 6, 7, 9, 10, 13, 14, 17, 18, 21].

**FL1 High Priority Proposal 4-1: Confirm the main bullet of the RAN1#104bis-e working assumption, i.e.:**

* **A RedCap UE cannot be configured with a non-initial (DL or UL) BWP (i.e., a BWP with a non-zero index) wider than the maximum bandwidth of the RedCap UE.**

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| **Company** | **Y/N** | **Comments** |
| Huawei, HiSi | Y |  |
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Regarding the sub-bullet in the working assumptions related to FG 6-x for BWP operation for the RedCap UE type capability, there are several views and considerations discussed in the contributions. A few contributions [6, 13, 14, 17, 18] indicate that this working assumption (as it is) can be confirmed while several other contributions [3, 5, 10, 16, 21, 31] further discuss relevant features for the RedCap UE type capability. Specifically, two issues related to SSB/CORESET #0 multiplexing and non-initial UL/DL BWPs in TDD are discussed in these contributions.

**Issue #1: SSB/CORESET #0 multiplexing:**

Based on FG 6-1 “Basic BWP operation with restriction”, it is mandatory for the non-RedCap UEs to support BWP with bandwidth restriction, i.e., an RRC configured DL BWP includes CORESET #0 and SSB. However, RedCap UEs are not able to simultaneously receive SSB and CORESET #0 for one special SSB/CORESET #0 multiplexing pattern in FR2, namely pattern 2 for 240 kHz SSB and 120 kHz PDCCH SCS (TS 38. 213, Table 13-10, indexes 6 and 7) [3, 5, 16, 21].

**Issue #2: Non-initial UL/DL BWPs in TDD:**

In TDD scenarios, if the UL BWP and DL BWP should have the same centre frequency and the RedCap UL BWP does not contain CORESET #0, the DL BWP also does not contain CORESET #0. Therefore, due to the RedCap bandwidth limitation particularly in FR1, a non-initial DL BWP for RedCap UEs may or may not contain CORESET #0 [3, 10].

Several contributions [3, 5, 31] indicate that RedCap UEs should support FG 6-1a “BWP operation without restriction on BW of BWP(s)”, implying that an RRC-configured DL BWP does not need to contain both SSB and CORESET #0. In addition, [31] discuss that a RedCap UE not having SSB in an active BWP need to support FG 1-5a for RSRP/RSRQ measurements of serving cell based on CSI-RS. Meanwhile, two contributions [16, 21] prefer not to have the special SSB/CORESET #0 configurations in cells supporting RedCap UEs to avoid the need for FG 6-1a.

Some relevant proposals and observations from the contributions are summarized below:

* Contribution [3] proposes that RedCap UEs support FG 6-1a “BWP operation without restriction on BW of BWP(s)”, implying that an RRC-configured DL BWP does not need to contain both SSB and CORESET #0.
* Contribution [3] furthermore proposes that in TDD, a non-initial DL BWP for RedCap UEs may or may not contain CORESET #0.
* Contribution [5] proposes that UE feature 6-1a “BWP operation without restriction on BW of BWPs” should be supported mandatorily for RedCap UEs.
* Contribution [31] argues that RedCap UE not having SSB in active BWP would need to support at least the following optional features:
	+ FG 6-1a including at least synchronization based purely on TRS,
	+ RSRP/RSRQ measurements of serving cell based on CSI-RS (FG 1-5a).
* Contribution [31] furthermore proposes that as part of the optional feature support (i.e. FG 6-1a) a UE may support active BWP not comprising a SSB and expresses that this would require changes to synchronization procedures of current implementations, to support synchronization based purely on TRS, and support RRM RSRP/RSRQ measurements based on CSI-RS without SSB in the BWP (FG 1-5a) as well.
* Contribution [21] suggests to discuss whether the RedCap UE may assume the bandwidth of the CORESET #0 and SSB does not exceed the maximum RedCap UE bandwidth and expresses a preference to put some restrictions on the possible SSB/CORESET #0 multiplexing pattern in FR2.
* Contribution [16] considers that FG 6-1a implies that frequency retuning based reception between SSB and CORESET #0 the impact on RedCap UE operations may be significant and that not supporting these few configurations in FR2 in cells supporting RedCap UEs may not impose a significant practical constraint.
* Contribution [10] proposes that separate initial BWP that does not contain CORESET #0 should be an optional capability for RedCap UEs and furthermore adds that with FG 6-x, separate initial BWP may not contain CORESET #0, and that in TDD, when separate initial UL BWP that does not contain CORESET #0 is configured, separate initial DL BWP also does not contain CORESET #0.

Considering the above views on both issues related to SSB/CORESET #0 multiplexing and TDD UL/DL BWPs for non-initial BWP operations, the FL proposes the following questions:

**Medium Priority Question 4-2:**

* **Should RedCap UEs support FG 6-1a (“BWP operation without restriction on BW of BWP(s)” as described in TR 38.822) as a mandatory feature in addition to FG 6-1 (“Basic BWP operation with restriction”)? Please provide a motivation for your answer.**

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| **Company** | **Y/N** | **Comments** |
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**Medium Priority Question 4-3:**

* **What other features (if any) than FG 6-1 and FG 6-1a (if supported) should be supported by RedCap regarding the BWP operation? Please provide a motivation for your answer.**

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| **Company** | **Comments** |
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# RF switching time

In the previous meeting, RAN1#104bis-e, no consensus could be reached regarding whether an LS should be sent to RAN4 for their input on RF switching time. The discussion was captured in [35] and a draft LS with the following LS text was provided in [36].

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| Overall descriptionRAN1 has discussed the RedCap WI objective on “Reduced maximum UE bandwidth” and would like to ask RAN4 whether it would be feasible to maintain the same RF switching times for RedCap UEs as currently specified for non-RedCap UEs or even reduce the RF switching times for RedCap UEs under the following assumptions with manageable impacts (to e.g. device cost, power consumption, and specifications):* The RF switching takes place between two frequency locations with different centre frequencies.
* The maximum UE RF bandwidth is 20 MHz for FR1 and 100 MHz for FR2, and the frequency change is up to 80 MHz for FR1 and up to 300 MHz for FR2.
* The RF bandwidth, SCS, QCL, and RRC configuration can be assumed to be the same before and after the RF switching, i.e. it is only the centre frequency that changes.
* The RF switching may take place during initial access or after initial access.

Actions**To RAN4:****ACTION:** RAN1 respectfully asks RAN4 to provide feedback on the question above on RF switching time. |

Discussions on this aspect are summarized below.

* Several contributions [3, 5, 11, 13, 14, 16, 20, 22, 25] indicate their support of sending an LS or the drafted LS to RAN4 to seek for their inputs on reasonable RF switching delays for potential new BWP switching mechanisms (e.g. fast BWP switching, virtual BWP switching, new BWP switching within a BWP group). The main purpose of sending an/the LS is to confirm the feasibility of BWP switching times, help to identify RAN1 specification impacts, assess the feasibility and challenges in supporting specific scenarios (e.g. where puncturing is applied or an active DL BWP may not include SSB and/or CORESET #0) and/or progress on down selection of the open issues discussed in Section 6.
* Nevertheless, as discussed in Section 6, contribution [11] states that the (virtual) BWP switching, is only necessary for FR2. In contribution [20], it further indicates that manageable impacts (to e.g. device cost, power consumption and specifications) should be assumed. Moreover, contributions [4, 25] propose that “Retuning of a BWP” shall be stated in the LS if it’s agreed to be sent. And contribution [25] indicates that the current 100 kHz raster would not allow fast BWP switching because of the time required to retune the synthesizer and discussion on frequency position limitation on RF retuning shall be discussed first and added in the LS.
* Contributions [7, 12] argue that fast BWP switching or symbol-level RF retuning gap would increase power consumption, UE complexity for RedCap UEs and would have negative impacts on UEs data rate, cancel the frequency diversity gain consider the time-domain resource overhead, and/or could affect the network performance for coexistence between RedCap and non-RedCap UEs. Contribution [12] further remarks that there is no need to increase RAN4’s workload before RAN1 reaches consensus on fast BWP switching.
* A few contributions [6, 7, 9, 11, 12, 21] argue that supports of new BWP hopping/retuning beyond the existing BWP switching methods are not necessary for RedCap UEs for both FR1 and FR2 or for FR1 and the current specified BWP switching delay is sufficient. Contributions [6, 12] nevertheless propose RAN1 to send an LS to confirm with RAN4 whether Rel-15/16 BWP switching delay requirements can be reused for RedCap UEs e.g. due to RedCap UEs reduced maximum UE bandwidth.

**FL1 High Priority Question 5-1:**

* **Companies are invited to comment on the need to send an LS on RF switching time to RAN4 and to provide text proposals on potential updates of the LS text in [36] (if necessary).**

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| **Company** | **Comments** |
| Huawei, HiSi | Agree with the need.TP is suggested considering that the intention is to inquire the possibility of keeping/reducing the delay used for BWP switching for non-RedCap UEs, rather than reducing the pure RF switching delay in our understanding.

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| Overall descriptionRAN1 has discussed the RedCap WI objective on “Reduced maximum UE bandwidth” and would like to ask RAN4 whether it would be feasible to maintain the same ~~RF~~ switching delay~~times~~ for RedCap UEs as currently specified for BWP switch delay for non-RedCap UEs or even reduce the ~~RF~~ switching delay~~times~~ for RedCap UEs under the following assumptions with manageable impacts (to e.g. device cost, power consumption, and specifications):* The switching include RF switching takes place between two frequency locations with different centre frequencies.
* The maximum UE RF bandwidth is 20 MHz for FR1 and 100 MHz for FR2, and the frequency change is up to 80 MHz for FR1 and up to 300 MHz for FR2.
* The RF bandwidth, SCS, QCL, and RRC configuration can be assumed to be the same before and after the ~~RF~~ switching, i.e. it is only the centre frequency that changes.
* The switching include RF switching may take place during initial access or after initial access.

Actions**To RAN4:****ACTION:** RAN1 respectfully asks RAN4 to provide feedback on the question above on ~~RF~~ switching time. |

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# BWP switching

In RAN1#104bis-e, there was some discussion related to BWP switching, BWP hopping, and BWP retuning, see [35]. This is further discussed in several RAN1#105-e contributions, as summarized below.

* Several contributions propose that some new BWP switching, hopping, or retuning mechanism is studied: [5, 11, 13, 16, 20, 22, 25]. Reduced BWP switching time may, for example, be enabled by imposing restrictions on that only the center frequency is changed, while retaining one or more of subcarrier spacing, BWP size, QCL properties, and other common RRC configuration parameters, and/or constraining the number of possible frequency locations. Feasibility of this may depend on RAN4 input on RF switching time, see Section 5.
* Some contributions argue that the current switching mechanisms are sufficient [6, 9, 21].
* One contribution [7] argues that fast BWP switching/frequency hopping should be discussed only in the context of achieving coverage recovery, and then whether switching/hopping is prioritized compared to other schemes.
* One contribution [11] suggests to introduce a “virtual narrow BWP hopping”, however only for FR2, whereas one contribution [3] suggests that if any new BWP switching, hopping, or retuning mechanism is introduced in the specification, it may be used in any frequency band, regardless of the frequency range.
* One contribution [11] suggests introducing a new mechanism for transitioning a UE to a narrow BWP after initial access, where the switching mechanism may be implicit or initiated/requested by the UE.

FL questions/proposals related to these aspects will be added and treated once aspects raised in other related sections of this FL summary have seen further progress.

# Other aspects

**RRM measurements:**

RRM measurement aspects were brought up in some contributions. Two contributions [11, 33] mention that it is beneficial to have a DL BWP configured for a RedCap UE containing an SSB for measurement. This may be transmitted on or off the sync raster. One contribution [5] instead proposes to rely on RF retuning between different 20 MHz (in FR1) regions for obtaining RRM measurements to avoid the overhead associated with additional SSBs.

**SRS and CSI measurements:**

In [20] it is suggested to consider supporting SRS transmissions or CSI measurement/report for link adaptation outside active BWP. Also, Sub-band CSI reporting is suggested as a means of reflecting the reduced RedCap UE bandwidth.

In [5] it is suggested to further study CSI measurement/reporting over frequency resources wider than the maximum bandwidth of RedCap UEs.

**Potential SUL support:**

In [29, 34], it is suggested that SUL is supported for RedCap UEs. The WID [1] notes that “This WI focuses on SA mode and single connectivity with operation in a single band at a time”, which seems to suggest that SUL support may not be in the current WI scope. Since this question is under discussion in RAN4, the FL suggestion is to await the outcome of the RAN4 discussion, to avoid parallel discussions in different working groups.

# References

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| --- | --- | --- | --- |
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| [3] | [R1-2104179](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104179.zip) | Reduced maximum UE bandwidth for RedCap | Ericsson |
| [4] | [R1-2104188](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104188.zip) | Discussion on Bandwidth Reduction for RedCap UEs | FUTUREWEI |
| [5] | [R1-2104283](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104283.zip) | Reduced maximum UE bandwidth | Huawei, HiSilicon |
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| [7] | [R1-2104428](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104428.zip) | Discussion on reduced maximum UE bandwidth for RedCap | Spreadtrum Communications |
| [8] | [R1-2104526](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104526.zip) | Discussion on reduced maximum UE bandwidth | CATT |
| [9] | [R1-2104543](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104543.zip) | Aspects related to reduced maximum UE bandwidth | Nokia, Nokia Shanghai Bell |
| [10] | [R1-2104616](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104616.zip) | Discussion on reduced maximum UE bandwidth | CMCC |
| [11] | [R1-2104677](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104677.zip) | BW Reduction for RedCap UE | Qualcomm Incorporated |
| [12] | [R1-2104710](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104710.zip) | Bandwidth reduction for reduced capability NR devices | ZTE, Sanechips |
| [13] | [R1-2104782](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104782.zip) | Discussion on reduced UE bandwidth | OPPO |
| [14] | [R1-2104851](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104851.zip) | Discussion on reduced maximum UE bandwidth for RedCap | China Telecom |
| [15] | [R1-2104881](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104881.zip) | Discussion on reduced maximum UE bandwidth | TCL Communication Ltd. |
| [16] | [R1-2104911](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104911.zip) | On reduced max UE bandwidth for RedCap | Intel Corporation |
| [17] | [R1-2105072](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105072.zip) | Reduced maximum UE band width for RedCap UEs | DENSO CORPORATION |
| [18] | [R1-2105110](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105110.zip) | On reduced maximum UE bandwidth for Redcap | Apple |
| [19] | [R1-2105217](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105217.zip) | Reduced maximum UE bandwidth for RedCap | Lenovo, Motorola Mobility |
| [20] | [R1-2105983](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2105983.zip)([Inbox](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Inbox/R1-2105983.zip)) | Bandwidth Reduction for RedCap UEs(revision of [R1-2105316](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105316.zip)) | Samsung |
| [21] | [R1-2105429](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105429.zip) | Aspects related to the reduced maximum UE bandwidth of RedCap | LG Electronics |
| [22] | [R1-2105567](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105567.zip) | Discussion on the reduced maximum UE bandwidth for RedCap | Xiaomi |
| [23] | [R1-2105593](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105593.zip) | Discussion on aspects related to reduced maximum UE bandwidth | NEC |
| [24] | [R1-2105635](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105635.zip) | Discussion on reduced maximum UE bandwidth | Sharp |
| [25] | [R1-2105679](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105679.zip) | Aspects related to reduced maximum UE bandwidth | Panasonic Corporation |
| [26] | [R1-2105703](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105703.zip) | Discussion on reduced maximum UE bandwidth for RedCap | NTT DOCOMO, INC. |
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| [28] | [R1-2105746](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105746.zip) | Reduced maximum bandwidth for RedCap UEs | InterDigital, Inc. |
| [29] | [R1-2105751](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105751.zip) | Discussion on reduced maximum UE bandwidth | China Unicom |
| [30] | [R1-2105800](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105800.zip) | Discussion on aspects related to reduced maximum UE bandwidth | ASUSTEK COMPUTER (SHANGHAI) |
| [31] | [R1-2105882](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105882.zip) | On aspects related to reduced maximum UE BW | Nordic Semiconductor ASA |
| [32] | [R1-2104184](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104184.zip) | Ensuring coexistence between RedCap and non-RedCap UEs | Ericsson, Deutsche Telekom, NTT DOCOMO, Softbank, Telecom Italia, Telstra, Verizon Wireless, Vodafone |
| [33] | [R1-2104370](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2104370.zip) | Discussion on reduced capability signaling | vivo, Guangdong Genius |
| [34] | [R1-2105535](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_105-e/Docs/R1-2105535.zip) | On RedCap UL transmission | Huawei, HiSilicon |
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