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

e-Meeting, 12th – 20th April, 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 concerns the Rel-17 work item for support of reduced capability (RedCap) NR devices [1]. Earlier RAN1 agreements for this work item are summarized in [2].

This document summarizes contributions [3] – [32] and captures the following email discussion for the RedCap WI.

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| //This one is to use NWM – please use ***RAN1-104b-e-NWM-NR-R17-RedCap-01*** as the document name  [104b-e-NR-R17-RedCap-01] Email discussion on aspects related to reduced maximum UE bandwidth– Johan (11)   * 1st check point: 4/15 * 2nd check point: 4/19 * 3rd check point: 4/20 |

The issues in this document are tagged and colour coded with High priority or Medium priority.

# Initial DL BWP

RAN1#104e made the following agreements related to initial DL BWP:

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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 |

One of the FFS identified in RAN1#104e is to discuss whether a RedCap UE can operate with an initial DL BWP wider than the maximum RedCap UE bandwidth during the initial access and after the initial access. Regarding initial and non-initial BWPs, some contributions indicate that it should be clarified that an initial BWP has an index 0 (i.e., BWP #0) while a non-initial BWP has a non-zero index, and that “BWP #0” and “initial BWP” are often used interchangeably in the NR specifications [5, 11]. One contribution further indicates that an initial BWP (BWP #0) can also be used after the initial access regardless whether it is configured using option 1 (without UE-specific configuration) or option 2 (with UE-specific configuration) [11]. The FL observes that this understanding/interpretation may not be shared by all contributions, and that the different understandings/interpretations may contribute to different views regarding whether a RedCap UE is allowed to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth during initial access.

There are different views regarding the operation of RedCap on an initial DL BWP larger than its bandwidth. Some contributions support that UE is allowed to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth during and after initial access [5, 11, 26, 30], while several other contributions argue that the RedCap UE should not be allowed to operate with an initial DL BWP wider than its maximum bandwidth [3, 4, 6, 7, 8, 12, 13, 14, 15, 18, 19, 23].

For initial access, contributions generally seem to agree that DL transmissions are confined within the MIB-configured CORESET#0 bandwidth, which does not exceed the RedCap UE bandwidth regardless of any SIB1 configuration.

**High Priority Proposal 2-1:**

* **During initial access, the initial DL BWP for RedCap UEs can be the same as the MIB-configured initial DL BWP for non-RedCap UEs, regardless of any potential SIB1 configuration of bandwidth.**

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| **Company** | **Y/N** | **Comments** |
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For after initial access, most contributions support not allowing RedCap UEs to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth. One contribution points out that BWP#0 configuration option 2 may require special consideration, and that one possible approach is that operators update their networks to use BWP#0 configuration option 1 for cells supporting RedCap UEs [5].

**High Priority Proposal 2-2:**

* **After initial access, at least for BWP#0 configuration option 1, a RedCap UE is not allowed to operate with an initial DL BWP wider than the maximum RedCap UE bandwidth.**
  + **FFS: BWP#0 configuration option 2.**

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# Initial UL BWP

RAN1#104e made the following agreements related to initial UL BWP:

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| Agreements:   * 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 |

One of the FFS identified in RAN1#104e is to discuss whether a RedCap UE can operate with an initial UL BWP wider than the maximum RedCap UE bandwidth during the initial access and after the initial access. There are different views regarding the operation of RedCap on an initial UL BWP larger than its bandwidth. A few contributions support that UE is allowed to operate with an initial UL BWP wider than the maximum RedCap UE bandwidth during and after initial access [11, 21, 28, 31], while several contributions argue that the RedCap UE should not be allowed to operate with an initial UL BWP wider than its maximum bandwidth [3, 4, 6, 8, 13, 14, 15, 18, 19, 20, 23]. In addition, [26] discuss that it needs to determine if configured, whether always configure a pair of initial BWPs for RedCap UEs, or could configure e.g., only a dedicated initial UL BWP.

**High Priority Proposal 3-1:**

* **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 between the following options.**
  + **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 is configured for RedCap UEs.**
  + **Option 3: The scenario is not allowed.**

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| **Company** | **Y/N** | **Comments** |
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**High Priority Proposal 3-2:**

* **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 between the following options.**
  + **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 is configured for RedCap UEs.**
  + **Option 3: The scenario is not allowed.**

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| **Company** | **Y/N** | **Comments** |
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# BWP/CORESET configuration

RAN1#104e made the following agreements related to BWP/CORESET configuration:

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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.   **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. |

An FFS identified in RAN1#104e is whether an additional CORESET and/or separate SIB-configured initial BWPs can be configured for RedCap for the purposes such as offloading, differentiation of RedCap vs. non-RedCap UEs, and different BWP#0 configuration options.

**Additional CORESET for scheduling of Msg2/Msg4/Paging/SI messages:**

There are different views regarding introducing an additional CORESET for offloading purposes. Several contributions [11, 12, 14, 18, 21, 22, 23, 27, 28, 29] state that having additional CORESET for scheduling of Msg2/Msg4/Paging messages (and perhaps but not necessarily for SI messages) may be beneficial for congestion mitigation and offloading purposes. Meanwhile, a few other contributions [3, 7, 8] argue that an additional CORESET is not needed in Rel-17 since the congestion is not expected to be significant. Also, [13] mentions that no special enhancements are needed for offloading of RedCap UEs.

**Medium Priority Question 4-1: Should configuration of 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** | **Motivation** |
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**Different SIB-configured initial BWP for RedCap UEs and non-RedCap UEs:**

Several contributions support that 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 [3, 5, 14, 16, 22, 27]. However, a few contributions [8, 11] discuss that there is no need to have a SIB-configured initial DL BWP for RedCap UEs which is different from the SIB-configured initial DL BWP for non-RedCap UEs. In [12], it is pointed out that having a separate SIB-configured initial DL BWP for RedCap depends on the need of offloading, early identification of RedCap UEs and coverage recovery. Also, [13] mentions that no special enhancements are needed for offloading of RedCap UEs and differentiation between RedCap and non-RedCap should be discussed as part of the early identification design.

Similarly, in UL, several contributions support that 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 [3, 5, 14, 16, 18, 22]. However, [8] argues that there is no need to have a SIB-configured initial UL BWP for RedCap UEs which is different from the SIB-configured initial UL BWP for non-RedCap UEs. Moreover, [11] concerns that a separate SIB-configured initial UL BWP for RedCap UEs can cause PUSCH resource fragmentation due to the PUCCH transmissions.

Initial BWP aspects are also discussed in other sections, related to operation in an initial BWP wider than the UE bandwidth (Sections 1 and 2) and as a solution for resolving issues related to potential UL transmission outside the UE bandwidth (Sections 5 and 6). The FL intention is to come back later to the question about whether to support different SIB-configured initial BWP for RedCap and non-RedCap UEs.

**Non-initial BWP operation:**

Several contributions [5, 6, 11, 18] discuss the possibility operation on a non-initial BWP wider than the UE bandwidth. The great majority view is that RedCap UE operation in a non-initial BWP (i.e., a BWP with a non-zero index) wider than the UE maximum bandwidth is not supported. One contribution [17] mentions that after initial access, to minimize the negative impact of reduced UE bandwidth, one possible direction is to support configuring BWP larger than the maximum UE bandwidth.

**High Priority Proposal 4-2:**

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

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| **Company** | **Y/N** | **Comments** |
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**High Priority Proposal 4-3:**

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

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| **Company** | **Y/N** | **Comments** |
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**SSB/CORESET#0 acquisition:**

Two contributions discuss a potential issue related to CORESET#0/SSB multiplexing patterns 2 with 240 kHz SSB SCS for SSB and 120 kHz PDCCH SCS [11, 6].

# RACH occasions

RAN1#104e 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 |

The views on the 4 options described in the above RAN1#104e agreement are split.

* Contributions [4, 11, 12, 17, 21, 25, 27, 28, 31, 32] consider Option 1, either as the most preferred solution or as a secondary preferred solution.
* Contributions [5, 6, 7, 12, 14, 16, 17, 18, 19, 20, 22, 23, 25, 27, 28, 32] consider Option 2, either as the most preferred solution or as a secondary preferred solution.
* Contributions [8, 6, 11, 13, 16, 18, 27, 31] consider Option 3, either as the most preferred solution or as a secondary preferred solution.
* Contributions [7, 14, 21, 27, 28, 32] consider Option 4, either as the most preferred solution or as a secondary preferred solution. Contribution [13] consider Option 4 as an add-on solution to Option 3, whereas contribution [22] consider Option 4 as an add-on solution to Option 2.
* Contribution [9] presents a new option which requires that the UE in SSB selection considers whether the associated RO is within the UE bandwidth. If the associated RO is not within the UE bandwidth, the UE should not select the SSB.

From the above, Option 2 receives the most support. Specific comments regarding benefits, advantages, drawbacks, concerns and impacts for each of the options in the RAN1#104e agreement are summarized below. The questions below intend to collect any additional input before the down-selection between the options.

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

Benefits/advantages:

* RedCap should support the function of RF retuning to address several other issues. [3]
* Allow RedCap UE to send PRACH outside of its initial uplink BWP. Thus, there is no need to restrict the configurations. [4, 11]
* Uplink resource fragmentation can be avoided. [11, 16]
* Allows the RedCap devices and the normal UEs to share the same initial UL BWP and PRACH resource. [17, 31]
* No impact on resource utilization. No impact on non-RedCap UEs. [25]
* No additional signalling needed. [28]
* The RF retuning time for intra-band operation is around 50-200 µs, which is far smaller than 10ms RAR window. Thus, it can be acceptable without impacts on non-RedCap UEs. [31]

Drawbacks/concerns/impacts:

* Potential specification impact may include a new timing relationship between PRACH and RAR (msg2) which shall take the retuning time into account. May need to consider additional delay for starting RAR window. [4, 11, 12, 17, 22, 28]
* Large specification and test efforts. [6]
* Feasibility should be confirmed, e.g. whether the time gap between SSB and RO, and the time gap between RO and RAR PDCCH, are enough for RF-retuning. [7]
* May complicate the initial access procedure and spends more time, thus may increase access latency. [9]
* Frequent RF-retuning may be unavoidable. Therefore, more power consumption would be expected for RedCap UEs. In addition, such RF-retuning would significantly increase the UE implementation complexity. [14]
* Coverage of UL channels is sacrificed. [16]
* RF re-tuning may require re-tuning time on symbol level, requiring of RAN4 evaluations. [24]
* The specification should be updated to allow RedCap UEs to transmit a PRACH outside the initial UL BWP, or to adjust the initial UL BWP to include the UE BW after RF-retuning. [28]

**Medium Priority Question 5-1: For Option 1 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**Option 2: Separate initial UL BWP(s) for RedCap UEs**

Benefits/advantages:

* The SIB-configured initial UL BWP for RedCap UEs can be different from the SIB-configured initial UL BWP for non-RedCap UEs. Flexible configuration. [3, 28]
* Support that a RACH occasion associated with the best SSB falls within the RedCap UE bandwidth. [5, 11, 14]
* Offloading of PRACH resource. Access capacity extension and avoid or reduce the network congestion or PRACH collision [5, 6, 7, 16, 28]
* Provide early identification. [5, 12, 16, 28]
* Coexistence between the RedCap and legacy UEs. Does not restrict PRACH configuration for normal UEs. [6, 12, 25]
* Reuse BWP framework to simplify specification impact. [16]
* Provides a very thorough solution which could solve all issues including the transmission of PUSCH and PUCCH when the initial UL BWP exceeds the RedCap UEs’ bandwidth. [17]
* A straightforward option. [18]
* No UL coverage loss. [19]
* The signalling overhead is marginal and even can be fully mitigated by defining some implicit rules without the need of explicit signalling. [19]

Drawbacks/concerns/impacts:

* The initial UL BWP and the initial DL BWP may have different central frequencies. Does not follow the current BWP design principle for unpaired spectrum thus it complicates the UE’s implementation. [4, 17]
* Increased gNB processing for PRACH. [5, 11]
* May cause higher specification impact. [7]
* Risk of PUSCH/PRACH resource fragmentation [11, 16, 25]
* Some resource utilization efficiency loss since normal UE and RedCap devices may not share certain channels or resources. [17]
* New configuration for SIB is needed. Need additional indication (either implicitly or explicitly) [25, 28, 31]
* Additional resources for RedCap UEs may be needed. [25]
* Even if the number of RedCap UEs is quite small, the gNB would always configure more than one initial UL BWP, which can be burden at network side. [31]

**Medium Priority Question 5-2: For Option 2 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**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)**

Benefits/advantages:

* The most straightforward option. [6, 11, 18, 31]
* gNB does not configure initial BWP that is beyond the maximum UE bandwidth. Therefore, this issue will not occur. [8, 14]
* Minimum specification impact. [11, 13, 25, 28]
* RedCap UEs can share RACH occasions with legacy UEs. The configuration of initial access for non-RedCap UEs can be reused. [13, 16]
* A subset of RACH occasions can be indicated with a mask, thereby ensuring that all occasions are within the RedCap UE bandwidth [13]
* Considering that access latency may not be an issue for RedCap UEs, the impact from multiplexing some of the ROs in time (rather than in frequency) may not have a significant impact on access latency for RedCap use-cases. [18]
* If ROs with this frequency domain restriction are deemed insufficient, then the PRACH configuration index with more occasions in time domain can be selected. [18, 22]

Drawbacks/concerns/impacts:

* The flexibility of the network configuration for legacy UE is impacted. PRACH configuration for normal UEs will be restricted by the maximum RedCap UE bandwidth. May increase the probability of the random-access collisions [4, 5, 13, 14, 16, 17, 25, 28, 31, 32]
* Putting restrictions on gNB implementation or specification. [7]
* May cause inflexibility or fragmentation of PUSCH resources. [9]
* Potential impact on PRACH capacity if restrictions are applied. [11]
* gNB configuration and proper scheduling can provide a certain degree of assistants, but not all. [15]

**Medium Priority Question 5-3: For Option 3 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**Option 4: Dedicated PRACH configurations (e.g., ROs) for RedCap UEs**

Benefits/advantages:

* Compared to the separate initial UL BWP, it has benefit of reducing signalling overhead. [5]
* FDM-ed RACH occasions can be guaranteed to fall inside RedCap UE bandwidth. [11]
* In addition to sharing RACH occasions with legacy UEs, at least some RedCap UEs may be configured with dedicated RACH occasions. [13]
* Early identification support by dedicated resource configuration. [16, 28]
* Few impacts on RedCap UEs. No/few impact on non-RedCap UEs. [25]
* Flexible configuration. [28]
* Beneficial for collision handling. [28]

Drawbacks/concerns/impacts:

* May complicate the gNB’s resource allocation and the resource utilization efficiency may degrade since Redcap UE and legacy UE can’t share the same PRACH resources. [4, 6, 11, 12]
* Lack of flexibility. [5]
* May cause more congestions. [6]
* Risk of over-splitting the RO. [7]
* May cause inflexibility or fragmentation of PUSCH resources. [9]
* Potential increase in gNB PRACH processing load. [11]
* Has the drawback of option 2 and does not have the flexibility of option 2. [12]
* More specification impacts. [16]
* Since UEs are not required to monitor all PRACH resource for the transmission of preamble, then configuring dedicated PRACH resource in option 4 to make sure all the PRACH resources are within RedCap UE’s bandwidth seems unnecessary. [17]
* New configuration for SIB is needed. Need additional indication (either implicitly or explicitly). [25, 28]
* Even if the number of RedCap UEs is small, the PRACH configuration for non-RedCap UEs cannot be shared with RedCap UEs and the gNB should always configure dedicated PRACH configuration. [31]

**Medium Priority Question 5-4: For Option 4 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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# PUCCH/PUSCH during initial access

RAN1#104e 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 |

The views on the 4 options described in the above RAN1#104e agreement are split.

* Contributions [17, 21, 22, 25, 28] consider Option 1, either as the most preferred solution or as a secondary preferred solution.
* Contributions [5, 6, 7, 12, 14, 16, 17, 18, 19, 20, 22, 23, 25, 28, 32] consider Option 2, either as the most preferred solution or as a secondary preferred solution.
* Contributions [7, 11, 12, 13, 17, 22, 32] consider Option 3, either as the most preferred solution or as a secondary preferred solution.
* Contributions [4, 6, 8, 13, 16, 18] (for PUSCH) consider Option 4, either as the most preferred solution or as a secondary preferred solution.

From the above, Option 2 receives the most support. Specific comments regarding benefits, advantages, drawbacks, concerns, or impacts for each of the options in the RAN1#104e agreement are summarized below. The questions below intend to collect any additional input before the down-selection between the options.

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

Benefits/advantages:

* RedCap should support the function of RF retuning to address a number of other issues. [3]
* Avoid PUSCH resource fragmentation. [4, 16, 28]
* No specification impacts. [7]
* No need to restrict the configurations. [11]
* Allow PUCCH resource sharing between non-Redcap and Redcap UEs during initial access and may benefit from the scheduling flexibility and spectrum efficiency perspective. [19]
* Can be combined with some modification of uplink transmission rules and disable frequency hopping of uplink transmissions. [21]
* No impact on resource utilization. [25]
* No impact on non-RedCap UEs. [25]
* No additional signalling. [28]

Drawbacks/concerns/impacts:

* Will complicate UE’s implementation. [4, 14]
* All the timing relationship between uplink and downlink messages shall be revisited. So, it will introduce more specification impact. [4, 6]
* RF retuning is not supported for PUSCH/PUCCH transmission. [5]
* Performance loss caused by RF retuning time. Coverage of UL channels is sacrificed [6, 11, 16, 17, 32]
* Large test efforts. [6]
* May not be feasible, especially for PUCCH with short duration. [7]
* Whether the option will have impact on scheduling Msg4 depends on the switching time. If the switching time is short, small or no specification impact is foreseen. [12]
* Frequent retuning may cause more power consumption for RedCap UEs. [14]
* Rely on early identification to allocate PUCCH resource. [16]
* Switching gap between two hops for RF retuning. It may require switching time of a few OFDM symbols depending on the subcarrier spacing. Requiring of RAN4 evaluations. [19, 23, 25, 28]
* Should be clarified that whether the fast frequency retuning capability is a reasonable assumption for (all) the RedCap UEs. [22]

**Medium Priority Question 6-1: For Option 1 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**Option 2: Separate initial UL BWP(s) for RedCap**

Benefits/advantages:

* The SIB-configured initial UL BWP for RedCap UEs can be different from the SIB-configured initial UL BWP for non-RedCap UEs. [3]
* Support PUCCH (for Msg4/[MsgB] HARQ feedback) and/or PUSCH (for Msg3/[MsgA]) transmissions fall within the RedCap UE bandwidth during initial access. [5, 11]
* Coexistence between the RedCap and legacy UEs. Few impacts on RedCap UEs. No/few impact on non-RedCap UEs [6, 25]
* May achieve UL offloading benefit. Avoid or reduce the network congestion. [6, 7, 16, 32]
* May jointly tackle the out-of-range issue of the best RO. [7, 32]
* Flexible configuration. Has the benefit that there is no restriction on Msg3 frequency hopping for normal UE. [12, 28]
* There is also no restriction on the bandwidth for resource allocation of Msg3 for normal UEs. [12]
* Has no specification impact on PUCCH/PUSCH frequency hopping. [14, 23]
* Early identification is naturally supported. [16, 28, 32]
* Reuse BWP framework to simplify specification impact. [16]
* Provide a thorough solution. [17]
* The concern of UL coverage loss caused by switching gap is addressed. [19]
* The signalling overhead is marginal and even can be fully mitigated by defining some implicit rules without the need of explicit signalling. [19]

Drawbacks/concerns/impacts:

* The central frequency of initial UL BWP is different with that of the initial DL BWP; Hence, this option will also complicate UE’s implementation significantly. [4]
* Higher specification impact than other options. [7]
* Risk of uplink (e.g., PUSCH) resource fragmentation. Negative impact on the resource utilization efficiency of the non-RedCap UEs [11, 16, 22, 25, 28]
* Has some constraints on frequency hopping and position of BWP if PUSCH resource fragmentation needs to be avoided. [11]
* How to maintain same centre frequency in the DL BWP and UL BWP in TDD case requires careful study. [17]
* Require early identification. [19]
* New configuration for SIB is needed. [25, 28]
* Additional resources for RedCap UEs may be needed. [25]

**Medium Priority Question 6-2: For Option 2 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**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)**

Benefits/advantages:

* Compared to the separate initial UL BWP, it has benefit of reducing signalling overhead. [5]
* Low specification impact. Feasible and simple solution. [7, 11, 22]
* Early identification support by dedicated resource configuration. [16]
* A new hopping pattern for RedCap UEs: RedCap UEs may have a different hopping pattern (or disabled frequency hopping) such that the frequency span of the hop is within the RedCap BW while they are operating in a larger initial UL BWP. [17, 23]
* Few impacts on RedCap UEs. No/few impact on non-RedCap UEs. [25]
* Flexible configuration; Beneficial for collision handling. [28]

Drawbacks/concerns/impacts:

* Sacrifice the UE’s frequency hopping gain. [4]
* Reduce the resource usage or scheduling flexibility (e.g., frequency hopping should be disabled). May cause more congestions. [5, 6, 11, 25]
* Coexistence with non-RedCap UE needs further study. [7]
* There is still restriction on the bandwidth for resource allocation of Msg3 for normal UEs. [12]
* More specification impacts. [16]
* Require early identification. [19]
* Loss in frequency diversity. May cause coverage loss. [22, 23, 32]
* New configuration for SIB is needed. Need additional indication (either implicit or explicit). [25, 28]
* Fragmentation of PUSCH resources for non-RedCap UEs. [28]

**Medium Priority Question 6-3: For Option 3 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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**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)**

Benefits/advantages:

* The initial UL BWP for RedCap UE shall be configured within the RedCap UE’s bandwidth. [4]
* The most straightforward option. The gNB does not configure initial BWP that is beyond the maximum UE bandwidth. Therefore, this issue will not occur. Minimum specification changes. [6, 8, 11, 25, 28]
* Work for Msg3 PUSCH if frequency hopping is not enabled. [14]
* The configuration of initial access for non-RedCap UEs can be reused. [16]

Drawbacks/concerns/impacts:

* Impact on the non-RedCap UE. [5, 11, 12, 14, 16, 17, 19, 23, 25, 32]
* Although no PUSCH resource fragmentation within the BWP, there might be fragmentation over the entire carrier bandwidth. [11]
* gNB configuration and proper scheduling can provide a certain degree of assistants, but not all. [15]
* Require early identification. [19]

**Medium Priority Question 6-4: For Option 4 in the RAN1#104e agreement, does the above summary regarding benefits, advantages, drawbacks, concerns and impacts fully capture the most important aspects? Please suggest any additional aspects that are important to consider.**

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| **Company** | **Y/N** | **Comments** |
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# BWP switching and other BWP operation aspects

In addition to the BWP related topics mentioned above, other aspects of BWP operation, including BWP switching, are discussed in several contributions. In this section, the functional aspects are mainly covered, whereas switching times are further discussed in the next section.

Some contributions raise a potential issue of the reduced UE bandwidth and/or operation in narrow BWPs in terms of e.g. reduced frequency diversity, and different mechanisms to mitigate this are proposed.

* Fast BWP switching (or inter-BWP frequency hopping) is proposed to be studied in [4, 10, 17, 18, 21, 27]. Reduced BWP switching time may, for example, be enabled by imposing restrictions on that only the centre 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.
* One contribution [17] argues for a selection between two directions: either supporting that a UE can operate in a BWP larger than the maximum UE bandwidth, or supporting BWP switching with reduced switching time.
* One contribution [5] 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.
* Some contributions argue that the current BWP switching mechanism is sufficient [8, 20].
* As an alternative to the BWP switching, one contribution proposes other mechanisms such as BWP hopping [20] for narrow active BWP (at least in FR2). Similarly, one contribution proposes BWP retuning [3] with a limited set of starting locations for the BWP.
* One contribution [20] 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.
* One contribution [27] suggests to further discuss whether RRC connected UE shall operate within multiple RB-sets of wide BWP or multiple narrow dedicated BWP will be configured to the UE.

It can be noted that some of these aspects were discussed already during RAN1#104e, see [33], but there were no agreements, and further discussion was postponed.

**Medium Priority Question 7-1: What mechanism(s), if any, should be supported in terms of fast BWP switching, BWP retuning, or BWP hopping?**

* **Option 1: No faster BWP switching or hopping mechanisms are introduced for RedCap UEs.**
* **Option 2: Fast switching between BWPs is introduced, e.g. with only changed centre frequency and/or other constraints.**
* **Option 3: BWP retuning or hopping (for a single BWP) is introduced.**
* **Option 4: Other mechanism(s), please describe.**

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| **Company** | **Option(s)** | **Comments** |
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# RF retuning time and BWP switching delay

RAN1#104e made the following agreements related to RF retuning time:

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| --- |
| **Conclusion:**  Discuss further in RAN1#104b-e whether or not to send LS to RAN4 regarding RF retuning time, and if so, the RAN1 details associated with question. |

Regarding RF retuning time and/or BWP switching delay the following main areas are discussed in a few contributions:

* **During initial access or after initial access**:
  + BWP hopping/retuning (i.e. switching of a BWP to another BWP having same or restricted configurations but different centre frequencies
  + RF retuning of multiple RB-sets within a BWP larger than RedCap UE’s BWP
  + RF retuning for DL-UL centre frequency alignment
* **Additional areas for initial access when the initial BWP is larger than UE maximum bandwidth**:
  + RF retuning for RACH occasions when the FDM-ed RACH occasions is outside RedCap UEs’ maximum bandwidth
  + RF retuning for PUCCH (for Msg4/MsgB HARQ feedback) and PUSCH (forMsg3/MsgA transmissions) where intra-slot frequency hopping is enabled, and the initial BWP is larger than RedCap UEs’ maximum bandwidth

**RF retuning time:**

Among the discussions in the contributions, a range of possible RF retuning times is provided or postulated:

* RF retuning time is likely to be much faster than the agreeded duplex retuning time for HD-FDD UE of 13 ms [8]
* RF retuning delay is not expected to be larger than the RF retuning delay in LTE-MTC which is up to 2 symbols with 15 kHz SCS (which is about 142 µs) [17].
* RF retuning time for intra-band operation is around 50-200 µs [11, 18, 31]
* ~200 ms could be an estimate for RF retuning [13]
* Gap between PDCCH and PUSCH by default (e.g. N2) in RRC connected state makes the potential frequency retuning feasible [7]
* Within a limited range of candidate centre frequencies, the retuning time could be reduced [18, 29]

In contribution [21], it is noted that the LS to RAN4 regarding RF retuning time shall assume same subcarrier spacing and/or bandwidth, as well as assuming DL is transmitted from the same RF at gNB side.

Furthermore, contributions [22, 25] mention that it should be clarified that whether fast frequency retuning capability is a reasonable assumption for (all) the RedCap UEs or the performance impact by RF retuning time should be carefully considered with RAN4.

**High Priority Question 8-1: Should RAN1 send an LS to ask RAN4 about the worst-case RF retuning time that would apply in case RF retuning within a BWP is supported? If so, please provide any comments on the detailed formulation of the question to RAN4 (for example, can RAN4 assume that the only thing that changes is the centre frequency?).**

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| **Company** | **Y/N** | **Comments** |
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**BWP switching delay:**

Regarding inter-BWP switching, several contributions indicates their interest in allowing RedCap UEs to perform an enhanced/fast version of BWP switching (i.e. BWP hopping or retuning during which the UE switches it’s source BWP a target BWP with same/similar BWP configurations but differs in centre frequencies).

The currently specified values (as depicted in the table below) for BWP switch delay are relatively long requiring multiple of slots. This long interruption time is contributed from several aspects such as the time required for PDCCH decoding, application of the RRC configuration of the new BWP, RF retuning time etc [3, 6, 10, 13, 18]. Contributions [3, 4, 10, 13, 17, 18, 21, 27] suggest that the inter-BWP hopping/retuning time can be much faster. The overall BWP hopping/retuning time could be potentially shortened to within a few OFDM symbols [18] as the main contributors to the delay time would be from RF retuning times and possibly AGC settling time (and the transition time required for PDCCH decoding and/or RRC configuration of the target BWP may be precluded).

To further reduce the transition time, it is proposed to limit BWP hoping/retuning to a limited range of candidate centre frequencies or preconfigured hops with smaller hop parameters [10, 18, 20] and possibly limited to a pair of BWP [10].

Table 8.6.2-1. BWP switch delay (in 3GPP TS 38.133)

|  |  |  |  |
| --- | --- | --- | --- |
|  | NR Slot length | BWP switch delay TBWPswitchDelay (slots) | |
|  | (ms) | Type 1Note 1 | Type 2Note 1 |
| 0 | 1 | 1 | 3 |
| 1 | 0.5 | 2 | 5 |
| 2 | 0.25 | 3 | 9 |
| 3 | 0.125 | 6 | 18 |
| Note 1: Depends on UE capability.  Note 2: If the BWP switch involves changing of SCS, the BWP switch delay is determined by the smaller SCS between the SCS before BWP switch and the SCS after BWP switch. | | | |

In contrast, contribution [14] indicates that due to reduced maximum UE bandwidth, RF retuning is required to support DCI-based BWP switch and timer-based BWP switch. Even though BWP parameter change has already been considered for existing BWP switch interruptions, since all configured BWPs are within the maximum non-RedCap UE bandwidth, further study on BWP switch delay for RedCap UEs is needed in RAN4 to evaluate the impact of additional RF retuning delay.

Contribution [21] further indicates that the LS to RAN4 shall on the BWP switching time or RF retuning time shall assume same subcarrier spacing and/or bandwidth, as well as assuming DL is transmitted from the same RF at gNB side.

**High Priority Question 8-2: Should RAN1 send an LS to ask RAN4 about the worst-case BWP switching delay that would apply in case faster BWP switching is supported? If so, please provide any comments on the detailed formulation of the question to RAN4 (for example, can RAN4 assume that the only thing that changes is the centre frequency?).**

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| **Company** | **Y/N** | **Comments** |
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# Other aspects

**RRM measurements:**

RRM measurement aspects were brought up in some contributions. Two contributions [6] and [20] 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. Two contributions instead highlight other means for obtaining RRM measurements to avoid the overhead associated with additional SSBs. [3] proposes to rely on RF retuning between different 20 MHz (in FR1) regions for performing measurements. [23] proposes to either use CSI-RS in narrow (non-initial) BWP or SSBs in other BWPs for measurements.

**SRS and CSI measurements:**

In [21] 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.

# References

|  |  |  |  |
| --- | --- | --- | --- |
| [1] | [RP-210918](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_91e/Docs/RP-210918.zip) | Revised WID on support of reduced capability NR devices | Nokia, Ericsson |
| [2] | [R1-2102220](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2102220.zip) | RAN1 agreements for Rel-17 NR RedCap | Rapporteur (Ericsson) |
| [3] | [R1-2102311](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102311.zip) | Discussion on reduced maximum UE bandwidth for RedCap | Huawei, HiSilicon |
| [4] | [R1-2102402](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102402.zip) | Discussion on reduced UE bandwidth | OPPO |
| [5] | [R1-2102460](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102460.zip) | Discussion on aspects related to reduced maximum UE bandwidth | Spreadtrum Communications |
| [6] | [R1-2102529](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102529.zip) | Discussion on reduced maximum UE bandwidth | vivo, Guangdong Genius |
| [7] | [R1-2102638](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102638.zip) | Discussion on reduced maximum UE bandwidth | CATT |
| [8] | [R1-2102649](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102649.zip) | UE complexity reduction aspects related to reduced maximum UE bandwidth | Nokia, Nokia Shanghai Bell |
| [9] | [R1-2102672](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102672.zip) | Reduced maximum UE bandwidth for RedCap | TCL Communication Ltd. |
| [10] | [R1-2102699](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102699.zip) | On reduced maximum bandwidth for RedCap UEs | MediaTek Inc. |
| [11] | [R1-2102722](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102722.zip) | Reduced maximum UE bandwidth for RedCap | Ericsson |
| [12] | [R1-2102734](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102734.zip) | Discussion on reduced maximum UE bandwidth | Asia Pacific Telecom, FGI |
| [13] | [R1-2102778](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102778.zip) | Bandwidth reduction for RedCap UEs | FUTUREWEI |
| [14] | [R1-2102854](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102854.zip) | Bandwidth reduction for reduced capability NR devices | ZTE |
| [15] | [R1-2102866](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102866.zip) | Discussion on UE complexity reduction for RedCap | China Telecom |
| [16] | [R1-2102889](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102889.zip) | Discussion on reduced maximum UE bandwidth | CMCC |
| [17] | [R1-2102988](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102988.zip) | Discussion on the reduced maximum UE bandwidth for RedCap | Xiaomi |
| [18] | [R1-2103038](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103038.zip) | On reduced BW support for RedCap devices | Intel Corporation |
| [19] | [R1-2103112](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103112.zip) | On reduced maximum UE bandwidth for Redcap | Apple |
| [20] | [R1-2103174](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103174.zip) | BW Reduction for RedCap UE | Qualcomm Incorporated |
| [21] | [R1-2103246](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103246.zip) | Discussion on bandwidth reduction for RedCap UEs. | Samsung |
| [22] | [R1-2103352](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103352.zip) | Aspects related to the reduced maximum UE bandwidth of RedCap | LG Electronics |
| [23] | [R1-2103421](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103421.zip) | Reduced maximum bandwidth for RedCap UEs | InterDigital, Inc. |
| [24] | [R1-2103455](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103455.zip) | Discussion on BWP | NEC |
| [25] | [R1-2103476](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103476.zip) | Discussion on reduced maximum UE bandwidth | Sharp |
| [26] | [R1-2103534](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103534.zip) | Reduced maximum UE bandwidth for RedCap | Lenovo, Motorola Mobility |
| [27] | [R1-2103540](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103540.zip) | Aspects related to reduced maximum UE bandwidth | Panasonic Corporation |
| [28] | [R1-2103583](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103583.zip) | Discussion on reduced maximum UE bandwidth for RedCap | NTT DOCOMO, INC. |
| [29] | [R1-2103650](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103650.zip) | On aspects related to reduced maximum UE BW | Nordic Semiconductor ASA |
| [30] | [R1-2103664](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103664.zip) | Discussion on aspects related to reduced maximum UE bandwidth | ASUSTeK |
| [31] | [R1-2103698](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103698.zip) | Discussion on reduced maximum UE bandwidth for RedCap UE | WILUS Inc. |
| [32] | [R1-2103767](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103767.zip) | Reduced maximum UE bandwidth for RedCap (revision of [R1-2103534](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103534.zip)) | Lenovo, Motorola Mobility |
| [33] | [R1-2101852](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_104-e/Docs/R1-2101852.zip) | FL summary #4 for UE complexity reduction for RedCap | Moderator (Ericsson) |