**3GPP TSG RAN WG1 #103-e R1-200xxxx**

**e-Meeting, October 26th – November 13th, 2020**

**Agenda item:** 8.6.3

**Source:** Moderator (Qualcomm Inc.)

**Title:** FL summary #2 on Coverage Recovery and Capacity Impact for RedCap

**Document for:** Discussion and Decision

# Introduction

This contribution summarizes the contributions submitted to AI 8.6.3 (Study on NR reduced capability devices – coverage recovery and capacity impact).

# Target Performance Requirements

**Open issue #1 is to define the target performance for coverage recovery.**

|  |
| --- |
| **Agreements**: Down-selection on the following options for the target performance requirement for RedCap UEs in RAN1#103-e (aim for early in the e-meeting):   * Option 1: The target performance requirement for each channel is identified by a target MCL or MIL or MPL within a reasonable deployment * Option 3: The target performance requirement for each channel is identified by the link budget of the bottleneck channel(s) for the reference NR UE within the same deployment scenario   + Note: The “bottleneck channel(s)” are the physical channel(s) that have the lowest MCL or MIL or MPL * The details for the target performance requirement are FFS |

According to the contributions submitted to this meeting, the companies’ views are summarized as follows:

* 6 companies support Option 1
  + Huawei, vivo, Xiaomi, Qualcomm, Apple, Panasonic [if the reasonable scenario can be agreeable]
* 11 companies support Option 3
  + Ericsson, ZTE, [FutureWei], CATT, Intel, LG, Nokia, Spreadtrum, Samsung, MediaTek, DOCOMO

For Option 1, the proponents also make the following proposals:

* The reasonable deployment can be typical scenario as defined in TR 38.913, for which the reference UE can work effectively with the satisfaction of ITU requirements [4].
* Target performance can be defined as the required MPL at the distance of being from the base station for hexagonal cells [3].

The concerns on Option 1 from the opponents are captured below.

* It is not clear how a reasonable deployment is defined in the RedCap coverage study [1]
* There is no agreement on the specific values for the parameters related to MPL and it would be difficult to align on the MPL calculation and get a suitable absolute target MPL value for Option 1 [5]
* May introduce unnecessary coverage optimizations for the RedCap UE [15]

Additionally, [1] and [5] have proposed to further enhance the target value of Option 2 to close the performance gap between RedCap and Rel-17 NR coverage enhancement UEs

* Consider the channel with the second-lowest MIL (MCL or MPL) as the bottleneck channel [1]
* Add an additional margin on top of the target value determined by the link budget calculation for Rel-15/16 UE [5]

From moderator perspective, more input is needed from companies to decide for Option 1.

* Whether the typical scenarios (i.e. Urban macro ISD 500m, Rural ISD 1732m, indoor ISD 20m) defined in TR 38.913 can be used as the reasonable deployment for determining the target performance
* Whether the target performance can be defined as the required MPL at the distance of being from the base station for hexagonal cells
* The values of the parameters related to MPL. Note the Rel-17 CE SI has concluded in RAN1#102-e that RAN1 will not further discuss on specific values for the parameters related to MPL.

Question 2-1: Companies are invited to input views for the above aspects in the table below.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | For FR1, we are okay to use a target ISD to calculate the target performance for coverage recovery. However, we think ISD 500m may be too large for Urban especially for 4GHz with 24dBm/MHz PSD. We think a small value can be considered.  For FR2, the target ISD based approach may not be sufficient. According to [4], no coverage problem is identified even with ISD=100m. Also, the value of shadow fading margin for MPL calculation should be discussed since the values for IMT-2020 self-evaluation are not available in such case. |
| Ericsson | We agree with the FL summary. The 3 issues listed above need to be addressed before it is possible to progress the discussion based on Option 1. |

For Option 3, the main concern is the coverage problem for Redcap UEs in Rel-17 network if the a Rel-15/16 NR UE is chosen as the reference NR UE. Also, due to different assumptions on antenna gains for link budget calculation, the variance of the bottleneck channel link budget performance by companies can be very large and it would be difficult to derive a representative value as the target performance.

From moderator perspective, for Option 3, the main focus is to identify the performance loss of RedCap UE relative to the reference NR UE and it is not necessary to define an absolute target performance. Therefore, based on Option 3, we could have company specific target performance and use it to identify the coverage limiting channels for RedCap UE and the amount of compensation.

Question 2-2: Companies are invited to input views for the above aspects in the table below.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Generally, PUSCH is the bottleneck channel for the reference NR UE. If the target performance for coverage recovery is based on PUSCH, there could be coverage imbalance for initial access between the reference and Redcap UE. For example, the coverage of the initial access channels (e.g. PDCCH CSS, Msg2, Msg3 or Msg4) for RedCap may be better than that of the bottleneck channel for the reference UE but worse than that of initial access channels. In such case, RedCap UE may not access to the network if the initial access channel coverage is based on the reference UE. We think the target performance should be defined to ensure the same target coverage for initial access for both RedCap and reference UE. Therefore, Option 3 is not sufficient, and the additional compensation should be also considered.  We support to use the company specific target performance to identify the coverage limiting channels and the compensation values based on each company evaluation results. Then by comparing companies’ results, we can agree on the channels needed for coverage recovery and derive a representative value for the amount of compensation. |
| Ericsson | We think the baseline should be Rel-15/16 NR UEs and network. It is premature to speculate about Rel-17 network and UE features.  We do agree with FL’s observation that differences in antenna gains assumptions may result in large variations in the link budget results. We would like to point out that this is also a problem for Option 1 in determining the target performance as well as in assessing which channels fall below the target performance and require coverage recovery.  For Option 3 though, the issue can be resolved if we can agree on the difference in terms of antenna gain correction factors between the unicast and non-unicast channels. |
| MediaTek | Rel-15/16 UE will coexist in Rel-17 network as well, Rel-15/16 UE MIL performance is representative of the target deployment.  The benefit of Option 3 is that it relies on a relative measure, removing slack variables that otherwise would need to be agreed upon if Option-1 is adopted. |

Question 2-3: For the target performance requirement, please indicate your preferred option? Companies are also invited to input views for the following moderator’s proposal.

**Moderator’s proposal**

* The coverage recovery target for each channel of RedCap UE corresponds to the link budget of the bottleneck channel for the reference NR UE
* A small amount of compensation (e.g. up to 3-4 dB) can be considered for a channel if the link budget for the channel exceeds that of the bottleneck channel for the reference NR UE but the margin is small
* Note: The “bottleneck channel” for the reference NR UE is the physical channel that has the lowest MCL or MIL or MPL

|  |  |  |
| --- | --- | --- |
| **Company** | **Option** | **Comments** |
| Qualcomm | Option 1 (FR1) or new moderator’s proposal | As commented above, Option 1 may be not sufficient for FR2. We are okay to consider the new moderator’s proposal to have a unified target for both FR1 and FR2. The additional compensation should be used to ensure the same target coverage for initial access channels for both the reference and RedCap UE.  For FR2, the new proposal may still not solve the initial access being worse than eMBB issue (especially the 2nd bullet). We suggest to look at initial access channels separately and make sure they are as good as initial access for Rel15/16, i.e., compensate to match Rel15/16. Then option 3 can be applied to the other channels. This way we can get the channels enhanced but have the same initial access performance as Rel15/16. |
| Ericsson | Option 3 | Simply because we think it is easier to progress forward based on Option 3.  We are fine with the 1st part of the FL proposal.  We do not support the 2nd part. If the link budget for channel X exceeds that of the bottleneck channel, there is no need to enhance channel X. |
| MediaTek | Option-3 | We agree on the first bullet point “The coverage recovery target for each channel of RedCap UE corresponds to the link budget of the bottleneck channel for the reference NR UE”.  We disagree on second bullet point. No need to have coverage compensation to a channel if the link budget for the channel exceeds that of the bottleneck channel for the reference NR UE. |

**Open issue #2: Select the performance metric from MIL, MCL, and MPL for coverage recovery analysis.**

The contribution [3] indicates MPL is more suitable than MIL or MCL for Option 1, and [5] proposes MIL is used as the performance metric for coverage bottleneck(s) identification. From moderator perspective, the selection is highly based on how the coverage recovery target is determined. Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* If target performance requirement is based on Option 1
  + Maximum pathloss loss (MPL) is used as the coverage evaluation metric
* If target performance requirement is based on Option 3
  + Maximum isotropic loss (MIL) is used as the coverage evaluation metric

Question 2-4: Companies are also invited to input views for the above moderator’s proposal.

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm | Y | We are okay with the moderator’s proposal. |
| Ericsson | Y | We support the FL proposal. |
| MediaTek | Y | MPL is MIL diminished by the penetration and fading margins.  MPL can specify/characterize a target deployment scenario.  MIL is sufficient to compare links formed by different channels, the assumption being that they are applied in the same deployment scenario.  MCL excludes the antennae and so would not take into account the differences between RedCap and NR in the case of Option 3. In Option 1 it also fails to capture the assumptions on the deployment properly. |

# Coverage Recovery

On RAN1#102e meeting, it was agreed to take the following steps to identify the channels which need coverage recovery and the corresponding coverage-recovery values. In the following subsections, we summarize the link budget analysis based on companies’ initial proposals.

Agreements:  
For the channel(s) affected by complexity reduction, the following methodology can be used to determine the target performance for coverage recovery.

* Step 1: Obtain the link budget performance of the channel based on link budget evaluation
* Step 2: Obtain the target performance requirement for RedCap UEs within a deployment scenario
* FFS on the target performance requirement
* Step 3: Find the coverage recovery value for the channel if the link budget performance is worse than the target performance requirement

FL note: The summary below only considers the results submitted in the contribution, and some evaluation results submitted to the [103-e-NR-RedCap-EvaluationResults] have not been included. Once there is an agreement on the target performance and the choice of the performance metric, the FL will update the summary to include all the evaluation results.

## FR1, Urban with the carrier frequency of 2.6 GHz

According to the contributions submitted to this meeting, the companies’ views on the bottleneck channel for the reference NR UE and the channels that need coverage recovery for Redcap UE in Urban scenario at 2.6GHz are summarized as follows, where the number in the bracket indicate the potential amount of coverage recovery for the channel.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Bottleneck channel for reference UE | Need coverage recovery RedCap (1T2R) | Need coverage recovery RedCap (1T1R) | Target performance |
| Huawei | PUSCH | PUSCH (~6.2 dB) | PUSCH (~6.2 dB) | Option 1/MPL  (Target ISD 350m) |
| vivo | PUSCH | PUSCH (7.73 dB) | PUSCH (7.73 dB) | Option 1/MPL  (Target ISD 350m) |
| CMCC | PUSCH | - | PUSCH (7.92 dB) | Option 1/MPL  (Target ISD 400m) |
| Apple | PUSCH | PUSCH  Msg3  PUCCH 22 bits | PUSCH  Msg2  Msg3  PUCCH 22 bits | Option 1/MPL  (Target ISD 400m) |
| Qualcomm | PUSCH | PUSCH (8.76 dB)  PUCCH 22bits (4.7 dB) | PUSCH (8.76 dB)  PUCCH 22 bits (4.7 dB) | Option 1/MPL  (Target ISD 350m) |
| Xiaomi | PUSCH | PUSCH  Msg3  PUCCH | PUSCH  Msg3  PUCCH  Msg2 | Option 1 |
| Ericsson | PUSCH | PUSCH (3 dB) | PUSCH (3 dB)  Msg2 (3.7 dB)  Msg4 (0.1 dB) | Option 3/MIL |
| FutureWei | PUSCH | - | PUSCH (3 dB)  Msg3 (~1 dB) | Option 3/(MIL) |
| vivo | PUSCH | PUSCH (2.81 dB) | PUSCH (2.81 dB) | Option 3/MPL |
| ZTE | PUSCH | - | PUSCH (3 dB) | Option 3/MIL |
| Intel | PUSCH | PUSCH (3 dB) | - | Option 3/MIL |
| CMCC | PUSCH | - | PUSCH (3 dB) | Option 3/MPL |
| Nokia | PUSCH | PUSCH (3 dB) | PUSCH (3 dB) | Option 3/MIL |
| Samsung | PUSCH | PUSCH (3 dB) | PUSCH (3 dB) | Option 3/MPL |
| DOCOMO | PUSCH | PUSCH (3 dB) | PUSCH (3 dB) | Option 3/MIL |
| Qualcomm | PUSCH | PUSCH (3 dB) | PUSCH (3 dB) | Option 3/MPL |

* For a RedCap UE with 2 Rx antennas
  + For Option 1, 5 companies indicate PUSCH, Msg3 and PUCCH are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (5/5)**
    - PUCCH PF3 22bits (3/5)
    - Msg3 (2/5)
  + For Option 3, 7 companies indicate only PUCSCH is coverage limited and requires compensation
    - **PUSCH (7/7)**
* For a RedCap UE with 1 Rx antennas
  + For Option 1, 6 companies indicate PUSCH, PUCCH, Msg3 and Msg4 are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH** (6/6)
    - PUCCH PF3 22bits (3/6)
    - Msg3 (2/6)
    - Msg2 (2/6)
  + For Option 3, 9 companies indicate PUSCH, Msg2, Msg3 and Msg4 are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (9/9)**
    - Msg3 (1/9)
    - Msg2 (1/9)
    - Msg4 (1/9)

Therefore, the moderator would like to propose the following.

**Moderator’s observation**

* PUSCH is the bottleneck channel for the reference NR UE and the channel that needs enhancement for RedCap UE in Urban scenario at 2.6GHz
* For a RedCap UE with 2 Rx antenna, all downlink channels can satisfy the target performance requirement although a coverage degradation is observed compared to the reference NR UE
* For a RedCap UE with 1 Rx antenna, PDSCH Msg2 and Msg4 exhibit a degradation close to the margin from the target performance and therefore a small amount of compensation can be considered

## FR1, Rural with the carrier frequency of 0.7 GHz

The companies’ views on the bottleneck channel for the reference NR UE and the channels that need coverage recovery for Redcap UE in Rural scenario at 700 MHz are summarized as follows.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Bottleneck channel for reference UE | Need coverage recovery RedCap (1T2R) | Need coverage recovery RedCap (1T1R) | Target performance |
| Huawei | PUSCH | No need for recovery | No need for recovery | Option 1/MPL  (Target ISD 1732m) |
| vivo | PUSCH | No need for recovery | No need for recovery | Option 1/MPL  (Target ISD 1732m) |
| Apple | PUSCH | No need for recovery | No need for recovery | Option 1/MPL  (Target ISD 1732m) |
| Qualcomm | PUSCH | No need for recovery | No need for recovery | Option 1/MPL  (Target ISD 1732m) |
| Xiaomi | PUSCH | - | PUSCH  Msg3  Msg2 | Option 1 |
| Ericsson | PUSCH | PUSCH (3 dB)  Msg3 (0.9 dB) | PUSCH (3 dB)  Msg3 (0.9 dB) | Option 3/MIL |
| vivo | PUSCH | PUSCH (3 dB)  PUCCH 22 bits (5.24 dB)  PUCCH 11 bits (2.84 dB)  Msg3 (0.67 dB) | PUSCH (3 dB)  PUCCH 22 bits (5.24 dB)  PUCCH 11 bits (2.84 dB)  Msg3 (0.67 dB)  Msg2 (2.49 dB) | Option 3/MPL |
| ZTE | Msg3 | - | PUSCH (2.63 dB)  Msg3 (3 dB) | Option 3/MIL |
| Intel | PUSCH | - | PUSCH (3 dB)  Msg3 (0.16 dB) | Option 3/MIL |
| Nokia | Msg3 | Msg3 (3 dB) | Msg3 (3 dB) | Option 3/MIL |
| Samsung | PUSCH | PUSCH (3 dB)  PUCCH 22bits (1 dB) | PUSCH (3 dB)  PUCCH 22bits (1 dB) | Option 3/MPL |
| DOCOMO | PUSCH | - | PUSCH (3 dB)  Msg2 | Option 3/MIL |
| Qualcomm | PUSCH | PUSCH (3 dB)  Msg3 (0.49 dB) | PUSCH (3 dB)  Msg3 (0.49 dB) | Option 3/MPL |

* For a RedCap UE with 2 Rx antennas
  + For Option 1,
    - For 4 companies presenting the results, all indicate that none of the channels of RedCap UE is coverage limited
  + For Option 3, 5 companies indicate PUSCH, Msg3 and PUCCH are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (4/5)**
    - **Msg3 (4/5)**
    - PUCCH PF3 11bits (1/5)
    - PUCCH PF3 22bits (2/5)
* For a RedCap UE with 1 Rx antennas
  + For Option 1,
    - 4 companies indicate none of the channels is coverage limited
    - 1 company indicate PUSCH, Msg2 and Msg3 are coverage limited
  + For Option 3, 8 companies indicate PUSCH, Msg2, Msg3 and PUCCH are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (7/8)**
    - **Msg3 (6/8)**
    - PUCCH PF3 11bits (1/8)
    - PUCCH PF3 22bits (2/8)
    - Msg2 (2/8)

Therefore, the moderator would like to propose the following.

**Moderator’s observation**

* PUSCH and Msg3 are coverage limited for both the reference NR UE and RedCap UE in Rural scenario at 700MHz
* All downlink channels other than Msg2 for RedCap UE with 1Rx and 2Rx in Rural scenario at 700MHz can satisfy the target performance requirement although a coverage degradation is observed compared to the reference NR UE
* The margin for PUSCH, Msg3 and PUCCH for RedCap UE are reduced due to the 3 dB reduction in antenna efficiency and a small amount of compensation may be needed

## FR1, Urban with the carrier frequency of 4 GHz

The companies’ views on the bottleneck channel for the reference NR UE and the channels that need coverage recovery for Redcap UE in Urban scenario at 4 GHz are summarized as follows.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Bottleneck channel for reference UE | Need coverage recovery RedCap (1T2R) | Need coverage recovery RedCap (1T1R) | Target performance |
| Huawei | PUSCH | PUSCH (~12 dB)  Msg3 (~2.3 dB) | PUSCH (~12 dB)  Msg3 (~2.3 dB) | Option 1/MPL  (Target ISD 350m) |
| vivo | PUSCH | PUSCH (9.99 dB)  PUCCH 22 bits (1.49 dB)  PRACH B4 (2.89 dB) | PUSCH (9.99 dB)  PUCCH 22 bits (1.49 dB)  PRACH B4 (2.89 dB)  PDCCH CSS (0.68 dB)  Msg2 (1.6 dB) | Option 1/MPL  (Target ISD 350m) |
| Qualcomm | PUSCH | PUSCH (6.24 dB)  PUCCH 22bits (2.8 dB)  Msg2 (2.4 dB) | PUSCH (6.24 dB)  PUCCH 22 bits (2.8 dB)  PDCCH CSS (2.8 dB)  PDSCH (0.8 dB)  Msg2 (6.29 dB)  Msg4 (3.4 dB) | Option 1/MPL  (Target ISD 250m) |
| Ericsson | Msg2 | PDCCH CSS (0.8 dB)  Msg2 (6.4 dB)  Msg4 (3.7 dB)  PUSCH (1.5 dB) | SSB (2.2 dB)  PDSCH (3.8 dB)  PDCCH CSS (3.7 dB)  Msg2 (11.2 dB)  Msg4 (7.6 dB)  PUSCH (1.5 dB) | Option 3/MIL |
| vivo | PUSCH | PUSCH (2.83 dB) | PUSCH (2.83 dB) | Option 3/MPL |
| ZTE | PUSCH | - | PDCCH CSS (4.46 dB)  Msg2 (1.35 dB)  Msg4 (1.13 dB)  PUSCH (3 dB) | Option 3/MIL |
| Intel | PUSCH | PUSCH (3 dB) | - | Option 3/MIL |
| Nokia | PUSCH | PUSCH (3 dB) | PUSCH (3 dB) | Option 3/MIL |
| Samsung | PUSCH | PUSCH (3 dB)  PUCCH 22bits (1 dB) | PUSCH (3 dB)  PUCCH 22bits (1 dB) | Option 3/MPL |
| DOCOMO | PUSCH | PUSCH (3 dB)  Msg2 | PUSCH (3 dB)  Msg2 (8.5 dB)  Msg4 (4 dB) | Option 3/MIL |
| Qualcomm | PUSCH | PUSCH (3 dB) | PUSCH (3 dB)  Msg2 (3.05 dB) | Option 3/MPL |

* For a RedCap UE with 2 Rx antennas
  + For Option 1, 3 companies indicate PUSCH, Msg3, PUCCH PF3 22bits, PRACH B4 and Msg2 are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (3/3)**
    - Msg3 (1/3)
    - PUCCH PF3 22bits (2/3)
    - PRACH B4 (1/3)
    - Msg2 (1/3)
  + For Option 3, 7 companies indicate PUSCH, PUCCH PF3 22bits, PDCCH CSS, Msg2 and Msg4 are coverage limited and therefore require some compensation for RedCap UE
    - **PUSCH (7/7)**
    - PUCCH PF3 22bits (1/7)
    - PDCCH CSS (1/7)
    - Msg2 (2/7)
    - Msg4 (1/7)
* For a RedCap UE with 1 Rx antennas
  + For Option 1, 3 companies indicate potential enhancements for PUSCH, Msg3, PUCCH PF3 22bits, PRACH B4, PDCCH CSS, Msg2 and PDSCH
    - **PUSCH (3/3)**
    - Msg3 (1/3)
    - PUCCH PF3 22bits (2/3)
    - PRACH B4 (1/3)
    - **PDCCH CSS (2/3)**
    - **Msg2 (2/3)**
    - PDSCH (1/3)
  + For Option 3, 7 companies indicate potential enhancements for PUSCH, PUCCH PF3 22bits, PDCCH CSS, Msg2, Msg4, SSB and PDSCH
    - **PUSCH (7/7)**
    - PUCCH PF3 22bits (1/7)
    - PDCCH CSS (1/7)
    - **Msg2 (3/7)**
    - **Msg4 (2/7)**
    - PDSCH (1/7)
    - SSB (1/7)

Therefore, the moderator would like to propose the following.

**Moderator’s observation**

* PUSCH is the bottleneck channel for the reference NR UE and the channel that needs enhancement for RedCap UE in Urban scenario at 4 GHz
* For RedCap UE with 1Rx and 2Rx in Urban scenario at 4 GHz, downlink channels including PDCCH CSS, Msg2 and Msg4 exhibit a degradation close to the margin from the target performance and a small amount of compensation can be considered

## FR2, Indoor with the carrier frequency of 28 GHz

The companies’ views on the bottleneck channel for the reference NR UE and the channels that need coverage recovery for Redcap UE in indoor scenario at 28 GHz are summarized as follows.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Bottleneck channel for reference UE | Need coverage recovery RedCap (100MHz, 1T1R) | Need coverage recovery RedCap (50MHz, 1T1R) | Target performance |
| vivo1 | PUSCH | No need for recovery | - | Option 1/MPL  (Target ISD 20m) |
| Ericsson | Msg4 | Msg2 (5.6 dB)  Msg4 (4.5 dB) | PDCCH CSS (1.9 dB)  Msg2 (5.6 dB)  Msg4 (4.5 dB) | Option 3/MIL |
| vivo1 | PUSCH | PDSCH (0.55 dB)  PDCCH CSS (2.92 dB)  Msg2 (4.04 dB)  Msg4 (0.84 dB)  PBCH (0.38 dB) | - | Option 3/MPL |
| ZTE | PUSCH | - | PDSCH (5.19 dB)  Msg2 (0.21 dB) | Option 3/MIL |
| Intel | PDSCH | PDSCH (4.1 dB)  PUSCH (for UE12 dBm) | - | Option 3/MIL |
| Nokia | PDSCH | PDSCH (3.2 dB) | - | Option 3/MIL |
| Samsung1 | PUSCH | - | PDSCH (2 dB) | Option 3/MPL |
| DOCOMO | Msg4 | PDSCH  Msg2  Msg4 | PDSCH (10 dB)  Msg2 (8.5 dB)  Msg4 (4 dB)  PDCCH CSS (2 dB) | Option 3/MIL |
| Qualcomm | PUSCH | PDSCH (1.1 dB) | PDSCH (5.4 dB) | Option 3/MIL |

Note 1: Max 12 dBm Tx power is assumed for both the reference NR and RedCap UE

* For a RedCap UE with max 100MHz BW and 1 Rx antennas
  + For Option 1,
    - Only one company presents the result and indicates none of the channel is coverage limited for RedCap UE
  + For Option 3, 6 companies indicate DL channels including PDCCH CSS, Msg2, Msg4 and PDSCH are coverage limited and therefore require some compensation for RedCap UE
    - **PDSCH (5/6)**
    - PDCCH CSS (1/6)
    - Msg2 (3/6)
    - Msg4 (3/6)
    - PBCH (1/6)
* For a RedCap UE with max 50MHz BW and 1 Rx antennas
  + For Option 3, 5 companies indicate DL channels including PDCCH CSS, Msg2, Msg4 and PDSCH are coverage limited and therefore require some compensation for RedCap UE
    - **PDSCH (4/5)**
    - PDCCH CSS (2/5)
    - Msg2 (3/5)
    - Msg4 (2/5)

Therefore, the moderator would like to propose the following.

**Moderator’s observation**

* PDSCH and PUSCH are the bottleneck channel(s) for the reference NR UE and the channels that need enhancement for RedCap UE in indoor scenario at 28GHz
* For RedCap UE with 100MHz BW and 1 Rx, the link budget performance of Msg2 and Msg4 may not satisfy the target performance and some compensation may be needed
* For RedCap UE with 50MHz BW and 1 Rx, the link budget performance of PDCCH CSS, Msg2 and Msg4 may not satisfy the target performance and some compensation may be needed

# Capacity impact

Four contributions [1, 3, 4, 24] have provided the SLS evaluation results of UE complexity reduction. The contributions [1, 4, 24] provided burst traffic evaluation results, and the contribution [3] provided the results for both full buffer and burst traffic evaluation.

For burst traffic evaluation, the assumed traffic model for RedCap UE is different by companies. In contributions [1, 4, 24], the IM model as defined in TR 38.840 is used and the averaged traffic ratio between the reference eMBB and RedCap UEs is relatively small, e.g. less than 2%. The very low data volume in the downlink is corresponding to some RedCap user cases with UL dominant traffic, e.g. video surveillance and industrial wireless sensor. In contribution [3], FTP model 3 is used for both eMBB and RedCap UEs by considering some video applications for wearable and video surveillance use cases.

With different assumption of traffic model for RedCap, the impact of UE complexity reduction on network capacity and spectrum efficiency could be different. The contributions [1, 4] have noted that RedCap UE may experience degraded performance due to cost reduction features, but there is little impact on the reference eMBB UE performance. The contribution [1] stated that the spectral efficiency in DL has a minor degradation with the introduction of small RedCap data volume even with a 50% fraction of RedCap users, and the spectral efficiency in UL is essentially unchanged. The contribution [4] noted that the introduction of RedCap UEs has little impact to the co-existing eMBB UEs in the system and the cell capacity (cell served throughput) is increased due to the introduction of RedCap UEs to the system. The contributions [1, 24] also noted that for the impact of UE complexity reduction, the 1 Rx antenna does not make an appreciable change on the user throughput performance of the eMBB UE compared to the 2 Rx antenna.

With FTP model 3 for RedCap UE, the contribution [3] stated that the loss of downlink SE is about 54% and RU is increased by 104% for 2 Rx RedCap UE and the SE loss will be up to 70% and RU will be increased by 166% if UE Rx antenna is further reduced to 1Rx for the assumption of 100% RedCap UE in network.

Hence, the moderator would like to propose the following.

**Moderator’s observation**

* The impact of complexity reduction to network capacity and spectrum efficiency is highly dependent on the traffic load from RedCap users
  + When data volume produced by RedCap UE is low, there is little impact on eMBB UE performance and little impact on cell-average spectral efficiency
  + When data volume produced by RedCap UE is high, the cell-average spectral efficiency in downlink has a considerable degradation especially for 1 Rx antenna

# Potential techniques

In this section, we summarize the proposals on potential techniques to enhance the performance for RedCap UE in various contributions under AI 8.6.3.

***Overlapping with Rel-17 CE SI***

Three contributions [4][9][11] have stated that the overlapping/interaction with Rel-17 coverage enhancement SI should be considered to reduce duplicate standardization effort. [4][9] proposed that some solutions for UL channels introduced in the Rel-17 coverage enhancement SI can be reused or tailored for RedCap UE and the enhancement of UL channel could be deprioritized in RedCap SI. One contribution [3] indicated some additional UL enhancements outside Rel-17 CE SI could also be considered considering the further loss of uplink coverage for RedCap UE due to the loss of antenna efficiency.

Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* The coverage enhancement schemes introduced in the Rel-17 CE SI could be reused or tailored to solve the coverage issue of RedCap UE.

***PDSCH and PUSCH coverage recovery***

One contribution [2] has stated that the existing Rel-15/16 coverage enhancement techniques are sufficient in compensating for the coverage loss from complexity reduction. In [12] it was mentioned that further extension of these techniques can be considered if larger coverage recovery is necessary. The contributions [5][8] and [14] proposed to consider slot aggregation enhancements, such as increasing the number of repetitions and dynamic indication of the number of repetitions.

Additionally, frequency domain-based enhancement schemes were also proposed in some contributions. [1] [5] [8] [11] [13] [18] [20] [22] [23] and [24] proposed frequency hopping enhancement to increase frequency diversity for RedCap UE. The contribution [3] stated that BWP switching in a larger bandwidth is beneficial not only for achieving frequency scheduling gain but also for achieving fast load balancing between narrow bands in a cell.

Several contributions proposed to consider improving channel estimation performance for RedCap UE. In [5], it was proposed that additional DMRS can be introduced to enhance the channel estimation. The contributions [5, 8, 11, 13, 24] proposed to consider DMRS bundling for enabling cross-slot channel estimation for better channel estimation performance. The contribution [8] also indicated that the increase of the granularity of PRB bundling in channel estimation could be beneficial for a flat channel.

Two contributions [3] and [24] proposed to consider some enhancements taking advantage of the stationary conditions of the UEs in some RedCap scenarios. The contribution [3] proposed to consider DMRS overhead reduction for stationary UEs and UEs with limited mobility. In contribution [24], it was proposed to consider techniques to reduce the payload size for the L1 measurement report and enhanced L1/L2 inter-cell mobility for stationary devices.

One contribution [3] also proposed to consider SUL for UL coverage enhancement for RedCap UE.

Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* Consider one or more of the following coverage recovery schemes for PDSCH and PUSCH
  + Slot aggregation including enhancement
  + Frequency hopping or BWP switching enhancement
  + Ways to improve channel estimation
  + DMRS overhead reduction
  + Enhanced L1/L2 inter-cell mobility
  + L1 measurement payload reduction
  + SUL

***Msg2/Msg4 coverage recovery***

Several contributions [2, 4, 5, 23] have stated that PDSCH repetition scheme can also be considered for broadcast PDSCH enhancement for RedCap UE.

Two contributions [2][24] proposed that the use of lower MCS table before the RRC configuration can be considered for coverage enhancement of channels such as Msg4.

One contribution [24] proposed to consider RAR enhancement when TBS scaling is used for improving the coverage of Msg2.

In contribution [5], it was mentioned that some recovery schemes for PDSCH such as frequency hopping enhancement and DMRS enhancement can be also suitable for Msg2/Msg4.

Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* Consider one or more of the following coverage recovery schemes for PDSCH Msg2/Msg4
  + Repetition/slot aggregation
  + Lower MCS table (Table 5.1.3.1-3 of 36.214)
  + TBS scaling
  + Frequency hopping enhancement
  + Ways to improve channel estimation

***Msg3 coverage recovery***

In contributions [5, 23], it was proposed to consider repetition for improving the coverage of Msg3.

In contribution [5], it was mentioned that some recovery schemes for PUSCH such as frequency hopping enhancement and DMRS enhancement can be also suitable for Msg3.

Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* Consider one or more of the following coverage recovery schemes for PDSCH Msg2/Msg4
  + Repetition/slot aggregation
  + Frequency hopping enhancement
  + Ways to improve channel estimation

***PDCCH CSS coverage recovery***

Most contributions proposed to consider repetition for improving PDCCH coverage. In contributions [24, 25], it was stated that PDCCH repetitions can be performed both within a slot and across slots. The contribution [21] proposed to consider only UE-transparent PDCCH repetition scheme and the UE-aware PDCCH repetition schemes are not considered for RedCap UE.

The contributions [1, 3, 5, 8, 11, 12, 23, 26, 27] stated that compact DCI is useful when the required coverage recovery is small.

The contributions [1, 5, 12, 13, 17, 26] proposed to support higher aggregation level, e.g. AL=24 or 32, to enhance PDCCH coverage. It is noted that a new CCE-to-REG mapping may need to be introduced if all CCEs of the higher AL are within a CORESET. In contribution [1], it was noted that a higher AL may be achieved by repetition.

In contributions [4, 7, 17, 18] it was proposed to configure more symbols for a CORESET or use CORESET bundling to increase the number of OFDM symbols for a PDCCH.

The contributions [1] proposed to consider frequency hopped CORESET for RedCap UE to increase frequency diversity. In contribution [17], it was stated that frequency hopping in a wide bandwidth region can be considered for inter-slot PDCCH repetition.

In contribution [12], it was noted that the specification impact of some recovery schemes can be expected to be high.

The contribution [4] stated that compatibility with normal UE should be considered for broadcast PDCCH enhancement if RedCap and normal UEs share the same initial DL BWP.

The contribution [15] proposed that PDCCH link adaptation could be used to improve PDCCH coverage. It was also stated in [15] that PDCCH coverage recovery should consider PDCCH overhead reduction and the congestion of CORESET 0 and initial BWP.

Hence, the moderator would like to propose the following.

**Moderator’s proposal**

* Consider one or more of the following coverage recovery schemes for PDCCH CSS
  + Compact DCI
  + Intra- and/or inter-slot repetition
  + Longer CORESET duration
  + Higher aggregation level of 24 or 32
  + Increase the number of OFDM symbols for a PDCCH
  + Frequency hopping

***Coverage recovery for other channels (SSB, PRACH, PUCCH)***

Two contributions [14][21] proposed a shorter SSB period of 5ms or 10ms can be considered for coverage recovery. One contribution [1] stated that the “keep trying” method can be used for improving the coverage of SSB. The contribution [12] noted that PBCH repetition design for coverage recovery must consider SSB structure for different sub-carrier spacings and different RF frequency ranges.

One contribution [1] indicated that coverage recovery for PRACH can be supported by repeating random access attempts and using longer PRACH preambles, which may not require specification enhancements.

One contribution [1] indicated that coverage recovery for PUCCH can be supported by using repetition or longer PUCCH format, which may not require specification enhancements.

# References

1. R1-2007531 Coverage recovery and capacity impact for RedCap Ericsson
2. R1-2007536 Coverage recovery for RedCap FUTUREWEI
3. R1-2007598 Functionality for coverage recovery, Huawei, HiSilicon
4. R1-2007670 Discussion on coverage recovery, capacity and spectrum efficiency impact, vivo, Guangdong Genius
5. R1-2007717 Discussion on coverage recovery for RedCap UE ZTE
6. R1-2007864 Coverage recovery for reduced capability NR devices CATT
7. R1-2007889 Coverage recovery and capacity impact TCL Communication Ltd.
8. R1-2007949 On coverage recovery for RedCap UEs Intel Corporation
9. R1-2009217 Coverage Recovery and Capacity Impact Panasonic Corporation
10. R1-2008018 Discussion on coverage recovery for RedCap UEs CMCC
11. R1-2008050 Discussion on the coverage recovery of reduced capability NR devices LG Electronics
12. R1-2008070 Functionality for coverage recovery Nokia, Nokia Shanghai Bell
13. R1-2008086 Discussion on coverage recovery for reduced capability device Xiaomi
14. R1-2008102 Discussion on coverage recovery and capacity impact Spreadtrum Communications
15. R1-2008172 Coverage recovery for low capability device Samsung
16. R1-2008262 Discussion on coverage recovery issues and evaluation OPPO
17. R1-2009173 Coverage recovery for RedCap Lenovo, Motorola Mobility
18. R1-2008367 Coverage recovery for Redcap devices Sony
19. R1-2008396 Coverage recovery for reduced capability UEs Sharp
20. R1-2008472 Functionality for Coverage Recovery for RedCap Apple
21. R1-2008512 Discussion on coverage recovery for NR RedCap UEs MediaTek Inc.
22. R1-2008518 On coverage recovery for reduced capability UEs Convida Wireless
23. R1-2008553 Discussion on coverage recovery for RedCap NTT DOCOMO, INC.
24. R1-2009310 Coverage Recovery for RedCap Devices Qualcomm Incorporated
25. R1-2008686 Coverage recovery for reduced capability NR devices InterDigital, Inc.
26. R1-2008728 Discussion on Coverage Recovery for RedCap UE WILUS Inc.
27. R1-2008740 Coverage recovery for RedCap UE Sequans Communications

# Appendix – RAN1 agreements

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| **RAN1 #101e**  Agreements: If/when coverage evaluations outside the CE SI are needed,   * The basic evaluation methodology is based on link-level simulation for FR1.   + ­Step 1: Obtain the required SINR for the physical channels under target scenarios and service/reliability requirements.   + ­Step 2: Obtain the baseline performance based on required SINR and link budget template.   + ­Note: aspects related to identifying target performance and coverage bottlenecks based on target performance metric is to be handled separately * The evaluation methodology for FR2 is the same as FR1.   Agreements: If/when link-level coverage evaluations outside the CE SI are needed,   * The CE SI link-level simulation assumptions can be used as a starting point. * For calibration purposes, the following settings can be used:  |  |  |  | | --- | --- | --- | | **Parameters** | **FR1 values** | **FR2 values** | | Scenario and frequency | Urban:  2.6 GHz (TDD) (primary choice)  4 GHz (TDD) (secondary choice)  Rural:  700 MHz (FDD) | Indoor: 28 GHz (TDD) | | Frame structure for TDD | For 2.6 GHz:  DDDDDDDSUU  (S: 6D:4G:4U)  For 4 GHz:  DDDSUDDSUU  (S: 10D:2G:2U) | DDDSU  (S: 10D:2G:2U) | | Channel model | TDL-C | TDL-A | | UE velocity | 3 km/h | 3 km/h | |  |  |  |   **RAN1 #102 e:**  Agreements: For the channel(s) affected by complexity reduction, the following methodology can be used to determine the target performance for coverage recovery.   * Step 1: Obtain the link budget performance of the channel based on link budget evaluation * Step 2: Obtain the target performance requirement for RedCap UEs within a deployment scenario * FFS on the target performance requirement * Step 3: Find the coverage recovery value for the channel if the link budget performance is worse than the target performance requirement   Agreements: Link budget evaluation for RedCap should include at least PDCCH/PDSCH and PUCCH/PUSCH.  Agreements: For initial access related channels, at least Msg2, Msg3, Msg4 and PDCCH scheduling Msg2/4 are included for link budget evaluation   * Other initial access related channels are not precluded   Agreements: The impact of small form factor is considered for all the uplink and downlink channels   * A 3dB loss of antenna gain is included in link budget calculation for FR1   + - FFS on the application to both FDD and TDD bands or only FDD bands [revised, see below]   Agreements: For link budget evaluation, the antenna gain loss due to the small form factor can be applied to all the FR1 bands   * For RedCap coverage analysis, the agreements in the Rel-17 CE SI regarding link budget template and antenna array gain are reused.   + Continue to discuss and decide the performance metric in RAN1-103 e-meeting   Agreements: Down-selection on the following options for the target performance requirement for RedCap UEs in RAN1#103-e (aim for early in the e-meeting):   * Option 1: The target performance requirement for each channel is identified by a target MCL or MIL or MPL within a reasonable deployment * Option 3: The target performance requirement for each channel is identified by the link budget of the bottleneck channel(s) for the reference NR UE within the same deployment scenario   + Note: The “bottleneck channel(s)” are the physical channel(s) that have the lowest MCL or MIL or MPL * The details for the target performance requirement are FFS   Agreements: For RedCap UE, adopt the following target data rates for link budget evaluation for FR1 Rural.   * 1 Mbps on DL and 100kbps in UL   Agreements: For RedCap UE, adopt the following target data rates for link budget evaluation for FR1 Urban.   * 2 Mbps on DL and 1Mbps in UL   Note: The 2Mbps target data rate in downlink is the scaled value of the 10Mbps in the CE SI by a factor of 0.2  Agreements:  For RedCap UEs, the target data rates for link budget evaluation for FR2 are as follows:   * 25Mbps for BW 50MHz/100MHz on DL and 5Mbps in UL   + Optionally, 12.5Mbps for BW 50MHz as the target data rate for DL, assuming the same DL PSD as that of BW 100MHz   + Note: in case of 50MHz BW, the maximum supported DL data rate is half that of the 100MHz BW in DL   Agreements: For RedCap coverage evaluation, the Rel-17 CE SI agreements on gNB antenna configuration, # gNB Tx/Rx chains, channel model and delay spread are reused with the following revision and/or addition   |  |  |  | | --- | --- | --- | | **Parameters** | **FR1 values** | **FR2 values** | | Channel model | TDL-C | TDL-A  CDL-A(optional) | | Delay spread | 300ns | 30ns | | UE velocity | 3 km/h | 3 km/h | | Antenna correlation | Low | Low | | # gNB Tx chains | 2 or 4 | 2 | | # gNB Rx chains | 2 or 4 | 2 |   For RedCap coverage evaluation, adopt the following table for the reference NR UE.   |  |  |  | | --- | --- | --- | | **Parameters** | **FR1 values** | **FR2 values** | | # UE Tx chains | 1 | 1 | | # UE Rx chains | Urban: 4 and Rural: 2 | 2 | | UE BW | Urban: 100 MHz (273 PRBs)  Rural: 20 MHz (106 PRBs) | 100 MHz (66 PRBs) |   For RedCap coverage evaluation, adopt the following table for the RedCap UE.   * + Other UE BWs are not precluded  |  |  |  | | --- | --- | --- | | **Parameters** | **FR1 values** | **FR2 values** | | # UE Tx chains | 1 | 1 | | # UE Rx chains | 1 or 2 | 1 or 2 | | UE BW | Urban: 20 MHz (51 PRBs)  Rural: 20 MHz (106 PRBs) | 50 MHz (32 PRBs) or  100 MHz (66 PRBs) |   Agreements: For RedCap coverage evaluation, reuse the Rel-17 CE SI agreements on channel specific parameters with the following revision and/or addition   * + TBS/PRB/MCS of PDSCH (except for Msg2)/PUSCH for the RedCap UE are based on the agreed target data rates or message sizes and reported by companies   + Adopt the following table for Msg2 evaluation     - Note: the TBS scaling is not precluded in the table entry “PRBs/TBS/MCS”  |  |  | | --- | --- | | **Parameters** | **Values** | | PRBs/TBS/MCS | MCS is fixed to zero. Companies to report the used number of PRBs and corresponding TBS value | | PDSCH duration | 12 OS | | DMRS configuration | Type I, 3 DMRS symbol, no multiplexing with data | | Waveform | CP-OFDM | | HARQ configuration | No retransmission |   Agreements:   * For SLS based capacity evaluation, use the assumption in TR 38.802, Table A.2.1-1 as the baseline. * For calibration purposes, the following settings can be used:  |  |  |  | | --- | --- | --- | | **Parameters** | **FR1 values** | **FR2 values** | | Layout | Single layer Macro layer: Hex. Grid | Single layer  Indoor floor: (12BSs per 120m x 50m)  Candidate TRP numbers: 3, 6, 12 | | Inter-BS distance | 500m | 20m | | Scenario and frequency | Dense Urban:  2.6 GHz (TDD) (primary choice)  4 GHz (TDD) (secondary choice)  Other scenarios (e.g. Rural 700MHz) are not precluded. | Indoor: 28 GHz (TDD) | | Frame structure for TDD | For 2.6 GHz:  DDDDDDDSUU (S: 6D:4G:4U)  For 4 GHz:  DDDSUDDSUU (S: 10D:2G:2U) | DDDSU (S: 10D:2G:2U) | | Channel model | 3Duma | 5GCM office | | UE distribution | 20% Outdoor in cars: 30km/h, 80% Indoor in houses: 3km/h | 100% Indoor: 3km/h | | Traffic model | Full buffer (Optional)  Non-full buffer traffic, e.g. FTP traffic model 3 for the reference NR UEs and the IM traffic model from TR 38.840 for RedCap UEs | | | Traffic load | Full buffer traffic (Optional):  10 users per cell including both RedCap and reference NR UEs  Non-full buffer traffic:  Low (e.g. <30%) and medium (e.g. 30%-50%) loading (resource utilization) | | | Percentage of RedCap UEs among total number of UEs  Note: Other UEs are the reference NR UEs | Full buffer traffic (Optional):  0, 20%, 50% (i.e. 0, 2 or 5 RedCap UEs per cell), 100% (as applicable)  Non-full buffer traffic:  0, 25%, 50%, 100% (optional, as applicable) | | |