**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 #8 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).

This document captures the following RAN1#103e RedCap email discussion.

|  |
| --- |
| [103-e-NR-RedCap-04] Email discussion for coverage recovery and capacity impact– Chao (Qualcomm)* 1st check point: 10/29
* 2nd check point: 11/4
* 3rd check point: 11/10
* Last check point 11/12
 |

In this round of the email discussion, please check the proposals/questions tagged ‘FL8’ (search for ‘FL8’).

# Target Performance Requirement

# Coverage Recovery

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

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

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

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

**[FL8] Proposal 3.4-2:**

* Observations for FR2 coverage recovery can be drawn separately for max TRP 12 dBm and max TRP 23 dBm

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | We prefer to use the same way as in CE, i.e. based on TRP 12dBm, otherwise, it may be inconsistent between different items.  |
| Samsung  | Y | Separate observations seem reasonable. |

**[FL8] Proposal 3.4-1A:**

* Adopted the updated TP in section 3.4 of R1-2009722 as baseline text for TR clause 9.1

(FL note: this is the TP for coverage loss for indoor 28GHz based on results for max TRP 12 dBm)

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Y |  |
| Samsung | Y |  |

## Conclusion

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| --- |
| Agreements:* Capture the following observations for FR2 coverage recovery to the TR 38.875
	+ For FR2, there is no assumption of reduced antenna efficiency for RedCap UE and the MIL of the UL channels is the same as the reference NR UE and coverage recovery for UL channels is not needed.
	+ [For RedCap UE with 100 MHz BW and 1Rx, although there is performance loss from reducing the number of Rx branches to 1, the MIL(s) of all the DL channels is better that that of the bottleneck channel for the reference NR UE and coverage recovery for DL channels is not needed. ]
	+ For RedCap UE with 50MHz BW and 1Rx, coverage recovery may be needed for PDSCH when the same target data rate as the reference NR UE is assumed, and the amount of coverage recovery to be considered is approximately [2-3 dB]
		- The tradeoff between data rate and coverage can be considered and the amount of coverage recovery may depend on this choice.
	+ The determination of which channels require coverage recovery and the amount of coverage recovery depend on the choice of the target for coverage recovery
		- E.g. coverage recovery may not be needed for FR2 indoor scenario when the target is based on an MPL value from a target ISD of 20m
		- ~~E.g. a large amount of coverage recovery may be needed for the initial access channels if the target is to achieve the same coverage for the initial access channels between RedCap UE and the reference NR UE~~
 |

**[FL8] Proposal 3.5-2**: Capture the following observation on FR2 coverage recovery to TR clause 9.1

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| --- |
| * For RedCap UE with 100 MHz BW, 1Rx and max TRP 12 dBm in FR2 indoor scenario, although there is performance loss from reducing the number of Rx branches to 1, the MIL(s) of all the DL channels is better that that of the bottleneck channel for the reference NR UE and coverage recovery for DL channels is not needed.
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Y |  |
| Samsung | Y |  |

# Capacity impact

**[FL8] Proposal 4-1B:** Capture the following observation on capacity impact to TR clause 10

|  |
| --- |
| For burst traffic evaluation with IM traffic model for RedCap users:* Although the 1 Rx RedCap users in the FR1 TDD bands do not make an appreciable change on the user throughput performance of the eMBB users compared to the 2 Rx RedCap users, the SLS evaluations do reveal that there is a considerable degradation in RedCap UE spectral efficiency if the number of Rx branches is reduced from 4 to 1, compared to reducing from 4 to 2
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | Our reading of the updated SID in RAN#88e is that the purpose of SLS is to evaluate the impact to network capacity and spectral efficiency due to the introduction of RedCap UEs in network serving eMBB users. There is no task for RAN1 to compare UE spectral efficiency between 1Rx and 2Rx by SLSIn this regard, the TP agreed during the last GTW session is sufficient, no need for additional TP.  |
| Samsung | N | Prefer not to draw new observations without sufficient discussion in the very last hours.  |
| Xiaomi | N | The comparison between the SE between 1Rx and 2Rx by SLS is out of scope.  |

# Potential techniques

## UL coverage recovery

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| --- |
| Agreements in Rel-17 NR RedCap:* Capture the following to the TR 38.875
	+ Coverage recovery for PUSCH was studied from several aspects, including cross-slot or cross-repetition channel estimation, lower DM-RS density in time domain, enhancements on PUSCH repetition Type A and/or Type B, frequency hopping or BWP switching across a larger system bandwidth
	+ Some techniques, such as cross-slot or cross-repetition channel estimation, lower DM-RS density in time domain, enhancements on PUSCH repetition Type A and/or Type B have been studied also in the Rel-17 coverage enhancement SI
	+ Potential specification impacts of frequency hopping or BWP switching across a larger system bandwidth include:
		- Frequency domain hopping offsets/positions
		- Faster switching/RF retuning time.
			* Note this aspect requires RAN4 involvement, where the corresponding study in RAN4 is not performed yet.
		- Transmission/reception interruption during RF retuning time

Agreements in Rel-17 NR RedCap:* Capture the following to the TR 38.875
	+ Coverage recovery for Msg3 was studied including repetition for Msg3 PUSCH initial and/or retransmission
	+ It is noted that enhancements on Msg3 PUSCH repetition have been studied also in the Rel-17 coverage enhancement SI

Agreement in Rel-17 CE SI: Capture the following observation into the TR.* Enhancements on PUSCH repetition type A is beneficial for PUSCH coverage enhancements for TDD. It is recommended to support enhancements on PUSCH repetition type A in Rel-17, including the following two options (potential down-selection during the WI phase):
	+ Option 1: Increasing the maximum number of repetitions, e.g., up to 32.
	+ Option 2: The number of repetitions counted on the basis of available UL slots.

Agreement in Rel-17 CE SI**:** Capture the following observation into the TR.Joint channel estimation is beneficial for PUSCH coverage enhancements. It is recommended to support Joint channel estimation or DM-RS bundling for PUSCH in Rel-17, including:* Joint channel estimation over consecutive PUSCH transmissions
* Inter-slot frequency hopping with inter-slot bundling
 |

**[FL8] Proposal 5.1-2A**: Capture the following into the TR.

|  |
| --- |
| * For PUSCH coverage recovery:
	+ It is recommended to support joint channel estimation or DM-RS bundling for PUSCH in Rel-17, including:
		- Joint channel estimation over consecutive PUSCH transmissions
		- Inter-slot frequency hopping with inter-slot bundling
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Y |  |
| Samsung |  | Either refer to CE SI for the techniques for PUSCH enhancement in general, or agree a full list. It seems only 2 out of 3 agreed recommendation are picked, we like to know why these two, why not TB across multiple slot?  |
| Xiaomi | Y |  |

**[FL8] Proposal 5.1-2B**: Capture the following into the TR

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| --- |
| * For PUSCH coverage recovery:
	+ It is recommended to support enhancements on PUSCH repetition type A for TDD in Rel-17, including the following two options (potential down-selection during the WI phase):
		- Option 1: Increasing the maximum number of repetitions, e.g., up to 32.
		- Option 2: The number of repetitions counted on the basis of available UL slots.
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Y |  |
| Samsung |  | Either refer to CE SI for the techniques for PUSCH enhancement in general, or agree a full list. It seems only 2 out of 3 agreed recommendation are picked, we like to know why these two, why not TB across multiple slot? |
| Xiaomi | Y |  |

**[FL8] Proposal 5.1-2C**: Capture the following into the TR

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| --- |
| * For PUSCH coverage recovery:
	+ It is recommended to support frequency hopping or BWP switching across a larger system bandwidth
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | The study of this feature is incomplete, no feasibility study was performed regarding faster BWP switching or RF retuning, therefore it shall not be recommended.  |
| Samsung | Y | OK for it since this is Recap specific solutions.  |
| Xiaomi | Y | The solutions to improve the MTC coverage can also be referredFrequency hopping and RF retuning is already supported in MTC for the purpose of coverage enhancement, so we don’t see any problem for the recommendation  |

**[FL8] Proposal 5.1-2D**: Capture the following into the TR

|  |
| --- |
| * For Msg3 PUSCH coverage recovery:
	+ It is recommended to support PUSCH repetition for Msg3 initial and/or retransmission
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | Y |  |
| Samsung | Y | OK for this since this has not been discussed yet in CE SI.  |
| Xiaomi | Y |  |

## PDSCH coverage recovery

## Msg2 and Msg4 coverage recovery

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| --- |
| Agreements in Rel-17 NR RedCap:* Capture the following to the TR 38.875
	+ Coverage recovery for Msg2 PDSCH was studied from several aspects, including TBS scaling [and Msg2 PDSCH repetition]
	+ It is noted that TBS scaling is an existing technique mandatory for Rel-15 UE
	+ Potential specification impacts of Msg2 PDSCH repetition (if supported) include
		- Msg2 PDSCH repetition configuration
		- Mechanism to differentiate enhanced UE and legacy UE, e.g., separate PRACH configurations (e.g, separate PRACH occasions or preambles)

Agreements in Rel-17 NR RedCap:* Capture the following to the TR 38.875
	+ Coverage recovery for Msg4 PDSCH was studied from several aspects, including scaling factor for TBS determination, PDSCH repetition and the use of the lower-MCS table.
	+ Some techniques, such as scaling factor for TBS determination and PDSCH repetition have been studied also in the Rel-17 coverage enhancement SI
	+ Potential specification impacts of using the lower-MCS table for Msg4 PDSCH include
		- Related signaling design
 |

**[FL8] Proposal 5.3-2A**: Capture the following into the TR

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| --- |
| * For Msg4 PDSCH coverage recovery:
	+ It is recommended to support TBS scaling for Msg4 PDSCH in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | Based on the observations, the coverage issue for MSG4 is only observed in case of gNB Tx power 24dBm/MHz but not for 33dBm/MHz. So the necessity of coverage recovery for MSG4 is not clear yet. Alternatively, it can be considered as lower priority with some simple solutions. Regarding the solutions, we think it is too early to recommend a particular one, there has been multiple solutions available as discussed in CE SI, which can be considered further if it can be agreed to support MSG4 PDSCH coverage recovery. Agreements: Capture the followings into the TR* Msg4 PDSCH enhancements were studied from several aspects, including introducing early CSI on Msg3 PUSCH for early link adaptation , scaling factor for TBS determination and PDSCH repetition.
* Potential specification impacts of early CSI on Msg3 PUSCH for early link adaptation include:
	+ CSI-RS resources configured during initial access.
* Potential specification impacts of scaling factor for TBS determination include:
	+ TBS determination.
* Potential specification impacts of PDSCH repetition include:
	+ PDSCH repetition configuration, DMRS design among PDSCH repetitions.
 |
| Samsung | N  | gNB implementation like lower MCS, more PRB allocation and lower-MCS table may be sufficient. |
| Xiaomi |  | We are OK to recommend solution for the Msg.4 coverage recovery. But we think the solutions discussed in CE SI should be captured as the starting point.  |

**[FL8] Proposal 5.3-2B**: Capture the following into the TR

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| --- |
| * For Msg4 PDSCH coverage recovery:
	+ It is recommended to support PDSCH repetition for Msg4 PDSCH in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | Same comment as the previous question.  |
| Samsung | N | gNB implementation like lower MCS, more PRB allocation and lower-MCS table may be sufficient. |
| Xiaomi |  | On the base repetition, we think the channel estimation improvement can be further added |

**[FL8] Proposal 5.3-2C**: Capture the following into the TR

|  |
| --- |
| * For Msg4 PDSCH coverage recovery:
	+ It is recommended to support the lower-MCS table for Msg4 PDSCH in Rel-17
 |

**If not, what modification is needed?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | Same comment as the previous question.  |
| Samsung |  | We are open for Msg 4 enhancement, However, we prefer to further discuss it in WI on which techniques to use other than only recommend one of them. |
| Xiaomi | Y |  |

**[FL8] Proposal 5.3-2D**: Capture the following into the TR

|  |
| --- |
| * For Msg2 PDSCH coverage recovery:
	+ It is recommended to support PDSCH repetition for Msg2 PDSCH in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | The existing TBS scaling mechanism is sufficient to compensate the observed MSG2 PDSCH coverage loss.  |
| Samsung | N | Rel-15 TBS scaling is sufficient |
| Xiaomi | Y | Due to the restricted UE bandwidth, the TBS scaling may be not sufficient when the number of RAR in one PDSCH is large, especially for Redcap with 1Rx |

## PDCCH coverage recovery

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| --- |
| Agreements in Rel-17 NR RedCap:* Capture the following to the TR 38.875
	+ Coverage recovery for broadcast PDCCH (PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS) was studied from several aspects, including PDCCH repetition, compact DCI, new AL [of 12, 24 or 32], PDCCH transmission via CORESET or search space bundling, PDCCH-less mechanism for SIB1 and/or SI message
	+ If PDCCH repetition is supported, the potential specification impacts include
		- Repetition configuration (e.g. intra-slot or inter-slot)
		- DMRS design among PDCCH repetitions
		- Search space design for PDCCH repetition
	+ If compact DCI is supported, the potential specification impacts include
		- DCI format with a small payload size
		- Reuse existing format by fixing some DCI bits
	+ If new AL is supported, the potential specification impacts include
		- Mechanism for codeword generation and mapping to CCEs
		- CORESET duration extension
		- Related signaling design
	+ If PDCCH transmission via CORESET bundling is supported, the potential specification impacts include
		- CORESET bundling configuration
		- DMRS design among CORESET bundling
	+ If PDCCH-less is supported, the potential specification impacts include
		- Mechanism or resource allocation for indicating scheduling information for SIB1 and/or SI message in L1 signals(s)/channels(s) other than PDCCH
	+ It is noted that some of the techniques may have compatibility issue if RedCap and normal UEs share the same initial DL BWP
 |

**[FL8] Proposal 5.4-2A**: Capture the following into the TR

|  |
| --- |
| * For PDCCH coverage recovery:
	+ It is recommended to support repetition for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | The necessity of PDCCH coverage recovery is not very clear (small gap observed for 24dBm/MHz gNB Tx power, but not for 33dBm/mhz case), it can be lower priority, if considered. PDCCH repetition has large spec impact thus not preferred.  |
| Samsung | Y | We support PDCCH recovery, but we prefer to further down select options in WI. |
| Xiaomi | Y | To address vivo’s concern, “if needed” can be added in the main bullet* For PDCCH coverage recovery (if needed):

It is recommended to support repetition for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17 |

**[FL8] Proposal 5.4-2B**: Capture the following into the TR

|  |
| --- |
| * For PDCCH coverage recovery:
	+ It is recommended to support compact DCI for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | The necessity of PDCCH coverage recovery is not very clear (small gap observed for 24dBm/MHz gNB Tx power, but not for 33dBm/mhz case), it can be lower priority, if considered. Compact DCI, New AL, CORESET bundling are all viable solutions with small or moderate spec impact, thus can be considered further in the WI phase (if PDCCH coverage recovery is supported), but we probably don’t need to down-select to a particular one right now.  |
| Samsung | Y | We support PDCCH recovery, but we prefer to further down select options in WI. |
| Xiaomi | Y | To address vivo’s concern, “if needed” can be added in the main bullet* For PDCCH coverage recovery (if needed):

It is recommended to support compact DCI for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17 |

**[FL8] Proposal 5.4-2C**: Capture the following into the TR

|  |
| --- |
| * For PDCCH coverage recovery:
	+ It is recommended to support new AL [of 12, 24 or 32] for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | The necessity of PDCCH coverage recovery is not very clear (small gap observed for 24dBm/MHz gNB Tx power, but not for 33dBm/mhz case), it can be lower priority, if considered. Compact DCI, New AL, CORESET bundling are all viable solutions with small or moderate spec impact, thus can be considered further in the WI phase (if PDCCH coverage recovery is supported), but we probably don’t need to down-select to a particular one right now. |
| Samsung | Y | We support PDCCH recovery, but we prefer to further down select options in WI. |
| Xiaomi | Y | To address vivo’s concern, “if needed” can be added in the main bullet* For PDCCH coverage recovery (if needed):

It is recommended to support new AL [of 12, 24 or 32] for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17 |

**[FL8] Proposal 5.4-2D**: Capture the following into the TR

|  |
| --- |
| * For PDCCH coverage recovery:
	+ It is recommended to support PDCCH transmission via CORESET or search space bundling for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo |  | The necessity of PDCCH coverage recovery is not very clear (small gap observed for 24dBm/MHz gNB Tx power, but not for 33dBm/mhz case), it can be lower priority, if considered. Compact DCI, New AL, CORESET bundling are all viable solutions with small or moderate spec impact, thus can be considered further in the WI phase (if PDCCH coverage recovery is supported), but we probably don’t need to down-select to a particular one right now. |
| Samsung | Y | We support PDCCH recovery, but we prefer to further down select options in WI. |
| Xiaomi | Y | To address vivo’s concern, “if needed” can be added in the main bullet* For PDCCH coverage recovery (if needed):

It is recommended to support PDCCH transmission via CORESET or search space bundling for PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS in Rel-17 |

**[FL8] Proposal 5.4-2E**: Capture the following into the TR

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| --- |
| * For PDCCH coverage recovery:
	+ It is recommended to support PDCCH-less for broadcast PDSCH carrying SIB messages in Rel-17
 |

**If not, what modification is needed?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | PDCCH-less broadcast has big impact in RAN1 and RAN2, and it may not provide a unified solution for FR1 and FR2, since only 1 PBCH spare bit in FR1.  |
| Samsung | Y | We support PDCCH recovery, but we prefer to further down select options in WI. |

## SSB and PRACH coverage recovery

# Possible proposals

# References

1. R1-2008865 Coverage recovery and capacity impact for RedCap Ericsson
2. R1-2007536 Coverage recovery for RedCap FUTUREWEI
3. R1-2008813 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