3GPP TSG RAN WG1 #102-e R1-200xxxx

e-Meeting, August 17th – 28th, 2020

**Agenda item: 8.8.2.3**

**Title: Feature lead summary on coverage enhancement for channels other than PUSCH and PUCCH**

**Source: Moderator (ZTE Corporation)**

**Document for:** **Discussion and Decision**

# Introduction

In the RAN plenary #86 meeting, a new SID on NR coverage enhancement was approved [1]. One objective of this study item is to identify the performance target for coverage enhancement for specific scenarios for both FR1 and FR2 and study the potential solutions.

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| * *Identify the performance target for coverage enhancement, and study the potential solutions for coverage enhancements for the above scenarios and services*
	+ *The target channels include at least PUSCH/PUCCH*
	+ *Study enhanced solutions, e.g., time domain/frequency domain/DM-RS enhancement (including DM-RS-less transmissions)*
	+ *Study the additional enhanced solutions for FR2 if any*
	+ *Evaluate the performance of the potential solutions based on link level simulation.*
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This contribution provides a summary of the contributions submitted under AI 8.8.2.3 and also Msg3/MsgA related enhancements in contributions under AI 8.8.2.1.

# Discussion

In [2][3][4][5][6][9][10][11][12][13][14][15], 12 companies observe that channels other than PUSCH and PUCCH could have potential coverage issue, and some potential techniques for enhancement are proposed. In [7], CATT shows that downlink channels are not the bottleneck except for the rural case with long distance, wherein the performance gap is too large to be compensated by physical techniques. In [8], Intel suggests RAN1 further study whether common control messages and physical channels during initial access need further coverage enhancement.

In this section, the potential techniques for channels other than PUSCH and PUCCH are summarized, by categorizing into high priority, medium priority and low priority.

## Discussion on proposals with high priority

### Msg3/MsgA PUSCH enhancements

In NR Rel-15 and Rel-16, PUSCH repetition is supported only for PUSCH scheduled by DCI 0\_1/0\_2 and only applied for RRC connected UEs. That is, Msg3 or MsgA PUSCH repetition scheduled by DCI 0\_0 during RACH procedure is not supported.

In [2][3][4][5][10][11][16][17][18][19][20][21][22][23], Msg3 PUSCH enhancements are proposed by 14 companies. Majority companies explicitly propose Msg3 PUSCH repetition as a solution. In [2], Huawei/HiSilicon also proposes to consider joint channel estimation for Msg3 PUSCH repetition. In [3][17], Nokia and China Telecom emphasize the importance of Msg3 PUSCH transmission which would impact the RRC connections establishment, and Nokia thinks the interplay between the coverage of msg1 and msg3 should also be considered. In [10], Samsung proposes to consider both PUSCH repetition type A and type B for Msg3 repetition. In [11], InterDigital mentions that refined beams may not be available for Msg3 PUSCH and repetition should be supported for enhancement. In [18][22][23], NEC, Ericsson and Qualcomm observes that using Msg3 repetition can reduce the latency compared to using re-transmission and can also avoid missed DCI detection risk or save PDCCH overhead. In [19], Intel observes that, given the nature of contention based RACH procedure, it may be difficult for gNB to schedule Msg3 retransmission as gNB may not know whether UE does not receive RAR UL grant or UE actually transmits Msg3 but gNB fails to decode it.

In [22], Ericsson proposes to consider multiple-antenna techniques for Msg 3 coverage enhancement including both open-loop Tx Diversity and closed-loop Tx Diversity. Open-loop Tx Diversity together with Msg3 repetition can improve Msg3 coverage through diversity gain and Tx chain power combining. Closed-loop Tx Diversity for Msg3 can benefit from coherent combining or antenna selection as well as Tx chain power combining .

In [5], ZTE provide some simulation results showing Msg3 PUSCH with 4 repetitions could provide about 5~5.5 dB gain over one repetition case, and Apple’s simulation results show that Msg3 PUSCH with 2 repetitions can provide about 2 dB gain [20].

In [4][16], vivo and CATT also believes MsgA repetition is necessary, where MsgA introduced in Type-2 random access procedure includes both PRACH and MsgA PUSCH. Figure 1 is an example for MsgA repetition from [4].



**Figure 1. MSGA repetition for coverage enhancement**

According to Rel-15 definition, Msg3 PUSCH here includes both Msg3 initial transmission scheduled by RAR and also Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by TC-RNTI.

Based on above, FL suggestion is to discuss the following proposal. Note that, the discussion here intends to discuss whether or how to enableMsg3/MsgA PUSCH repetition, how to indicate the number of repetitions, design of repetition pattern and multiple-antenna techniques etc. The enhancements may be potentially borrowed from normal PUSCH repetition like joint channel estimation will be first discussed in PUSCH enhancement AI.

***Proposal 1:******Study Msg3/MsgA PUSCH enhancement in NR coverage SI.***

* ***Study at least Msg3/MsgA PUSCH repetition***
* ***FFS whether or how to enable the repetitions.***
* ***FFS how to indicate the number of repetitions.***
* ***FFS the repetition pattern, e.g. the association with PRACH and PUSCH repetition type.***
* ***FFS multiple-antenna techniques.***

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| CATT | Support FL’s proposal. |
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### PRACH enhancements

According to NR Rel-15 and Rel-16 specification, PRACH includes both Msg1 for Type-1 random access procedure (namely the Rel-15 CBRA and CFRA) and PRACH of MsgA for Type-2 random access procedure (namely the Rel-16 2-step RACH).

In [3][4][5][9][10][15], PRACH enhancement for NR coverage are proposed. In [4], vivo suggests PRACH repetition should be carefully studied taking different aspects into account, such as coverage distance, frequency band and PRACH format, and coexistence of legacy PRACH transmission. In [5][10][15], ZTE, Samsung and Qualcomm believe PRACH repetition is beneficial in terms of beam refinement. In [9], OPPO thinks PRACH repetition can be considered at least for FR2.



**Figure 2. PRACH repetition with same Tx beam and different Tx beams.**

Based on above, FL suggestion is to discuss the following proposal.

***Proposal 2: Study PRACH repetition for NR coverage enhancement.***

* ***FFS whether or how to enable the repetitions.***
* ***FFS the repetition pattern.***
* ***FFS the applicable PRACH format.***
* ***Note, PRACH includes both Msg1 for Type-1 random access procedure and PRACH of MsgA for Type-2 random access procedure.***

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| CATT | There are abundant PRACH formats designed for both FR1 and FR1, including the PRACH format, the PRACH configuration and so on. The requirement of PRACH is definitely one of the considerations when we design the RACH procedure. Not sure why do we need to re-consider the PRACH design. Furthermore, there are no coverage issue in our simulation in both FR1 and FR2.Could we make the main bullet more general considering the above comments, such as add a condition like below?***Proposal 2: Study PRACH repetition for NR coverage enhancement if PRACH is the bottleneck.***  |
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## Discussion on proposals with medium priority

### Beam refinement during initial access

During initial access, the gNB transmits a SSB block with a relatively wide beam due to limited number of SSB blocks. The maximum number of SSB beams is 4 or 8 in FR1, and 64 in FR2. The relatively low SS/PBCH beam gain is one important factor that makes channels during initial access to be the coverage bottleneck.

In [5][6][10][11][13][15], some beam management issues are identified and correspondingly beam refinement enhancements are proposed. In [5][6], ZTE and Sony propose to increase the number of SSBs which could be directly used to refine SSB beams for better coverage. Polarization of SSB is also mentioned in [6].

In [10], Samsung observes that a time required for the UE to complete initial access is relatively long because UE can only use one beam per Msg1 transmission. A longer initial access time may also increase the possibility that the SSB the UE selected and obtained system information does not remain the “best” SSB, for example due to UE mobility. An example is shown in Figure 3.



**Figure 3. Impact of preferred DL beam changed during random access**

In [11], InterDigital proposes that, if PDCCH repetition is supported for Msg2, one possible enhancement is that the UE reports a channel quality estimate and/or an indication of the best PDCCH instance as part of Msg3. This would support beam refinement when the network uses different beams for different PDCCH instances.

In [13], Ericsson observes that, if an early CSI report is available during random access, array gain can improve coverage of downlink channels during random access without the increased overhead needed by low code rate PDSCH transmission. Therefore, they propose to study techniques to provide CSI during random access.

In [15], Qualcomm proposes to enable enhanced UE-side beam refinement or gNB-side beam refinement during RACH for coverage enhancement.

Based on above, FL suggestion is to discuss the following proposal.

***Proposal 3: Study whether/how to enable potential techniques for beam refinement during random access procedure.***

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| CATT | We are OK with the proposal |
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### PDCCH enhancements

In [5][6][9][11][12][14][15], 7 companies propose to consider PDCCH enhancements for NR coverage. In [5][9][11][15], the proposed enhancements is mainly targeting for broadcast PDCCH due to the limited SSB beam gains.

In Table 1, the potential techniques proposed by companies for PDCCH enhancement are listed.

**Table 1- Potential techniques for PDCCH enhancement**

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| **Technique** | **More detailed views from companies** |
| PDCCH repetition[5][6][9][11][12][14][15] | PDCCH repetition in the time or frequency domain with or without joint-decoding can be considered [5].PDCCH repetition is at least for FR2 [9].PDCCH repetition is already supported by NB-IoT and eMTC. If necessary this technique can be re-used by NR [12].Support Msg2 PDCCH repetition in time domain in FR2 [15]. |
| Compact DCI[5][6][14] | Study compact DCI for broadcast PDCCH [5]. |
| PDCCH-less[5] | Study PDCCH-less for broadcast PDCCH as specified in LTE MTC for SIB message transmission [5].  |
| Higher aggregation level [6][9][12][14] | The reduced complexity UE may not get the benefits of higher AL due to bandwidth limitation [12]. |
| Extension of PDCCH OFDM symbols[14] | Consider 4 or 6 OFDM symbols for PDCCH [14]. |
| DMRS enhancements[6] | The optimal quantity and type of DMRS for different conditions and how this can be dynamically controlled can be studied in this study item [6]. |
| Time interleaving[6] | Time diversity can be achieved by time interleaving transmissions [6]. |
| Small cells / relays/ Sidelink relay[6] | RAN1 could consider the coverage implications of the use of sidelink relaying in the study item [6] |

To avoid any potential misunderstanding, it would be better to clarify the exact channels that broadcast PDCCH includes. Based on FL understanding, it includes PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.

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| - a Type0-PDCCH CSS set configured by *pdcch-ConfigSIB1* in *MIB* or by *searchSpaceSIB1* in *PDCCH-ConfigCommon* or by *searchSpaceZero* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a SI-RNTI on the primary cell of the MCG- a Type0A-PDCCH CSS set configured by *searchSpaceOtherSystemInformation* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a SI-RNTI on the primary cell of the MCG- a Type1-PDCCH CSS set configured by *ra-SearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a RA-RNTI, a MsgB-RNTI, or a TC-RNTI on the primary cell- a Type2-PDCCH CSS set configured by *pagingSearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a P-RNTI on the primary cell of the MCG |

Based on above, FL suggestion is to discuss the following proposal.

***Proposal 4: Study PDCCH enhancement for NR coverage enhancement.***

* ***Study at least PDCCH repetition.***
* ***FFS other enhancements.***
* ***For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.***

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| CATT | We are generally fine with the proposal. However, as we commented on the online session, any change on the broadcast PDCCH should be very careful and the motivation should be verified very well. Furthermore, the third bullet seems not necessary as it is the common understanding of what broadcast PDCCH is. If the intention is to provide more information on the target PDCCH, it may be better to put an FFS such as CSS or USS.Hence we propose the following modification based on FL’s proposal.***Proposal 4: Study whether and how to enhance PDCCH ~~enhancement~~ for NR coverage enhancement.*** * ***Study at least PDCCH repetition.***
* ***FFS other enhancements.***
* ***FFS CSS and/or USS ~~For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set~~.***
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## Discussion on proposals with low priority

### PDSCH enhancement

In [6], Sony proposes to consider coverage enhancement techniques for PDSCH including DMRS enhancements, time interleaved transmissions, relaying (including sidelink relaying) in both FR1 and FR2. In addition, UE antenna configuration (antennas/panel, spherical coverage, multi beam capability, beam correspondence) and reflective arrays are proposed for FR2 only.

In [12], Apple proposes to consider time domain repetition, frequency hopping and DMRS enhancement for PDSCH enhancement. Basically, the PUSCH coverage enhancement techniques could be re-used for PDSCH.

In [13], Ericsson observes that Msg4 PDSCH has worse coverage than other DL PDSCH. Because Msg4 PDSCH doesn’t support beam management or PDSCH slot aggregation since RRC connection is not established yet, nor does it support TBS scaling which is applicable for Msg2 PDSCH scheduled by RA-RNTI.

FL’s view is that, if Msg 4 is the coverage bottleneck, the same could be also for Msg2/MsgB PDSCH which also doesn’t support beam management or PDSCH slot aggregation.

Based on above, FL suggestion is to discuss the following proposal.

***Proposal 5: Discuss whether/how to enhance PDSCH in NR coverage SI, e.g. in the following aspects.***

* ***Time domain repetition***
* ***Frequency hopping***
* ***DMRS enhancement***
* ***Potential enhancements to broadcast PDSCH.***

Companies are invited to provide views on the above proposal.

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| **Companies** | **Comments** |
| CATT | We don’t think there is any necessity to enhance PDSCH. |
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## Others

Companies are invited to provide additional proposals/comments, if any, in the below table.

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| **Companies** | **Comments** |
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# Reference

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2. R1-2005274 Discussion on the potential coverage enhancement solutions for other channels Huawei, HiSilicon
3. R1-2005301 Discussion on potential approaches and solutions for NR coverage enhancement: other channels than PUSCH and PUCCH Nokia, Nokia Shanghai Bell
4. R1-2005397 Discussion on coverage enhancement for channels other than PUCCH and PUSCH vivo
5. R1-2005429 Discussion on potential techniques for channels other than PUSCH and PUCCH ZTE
6. R1-2005586 Coverage enhancement for channels other than PUSCH and PUCCH Sony
7. R1-2005726 Disucssion on coverage enhancement for channels other than PUSCH and PUCCH CATT
8. R1-2005891 Discussion on NR coverage enhancement for other physical channels Intel Corporation
9. R1-2006049 Enhancement on NR channels for coverage OPPO
10. R1-2006164 Coverage enhancement for channels other than PUSCH and PUCCH Samsung
11. R1-2006292 Coverage enhancement for initial access InterDigital, Inc.
12. R1-2006532 On potential techniques for PDCCH and PDSCH coverage enhancement Apple
13. R1-2006615 Coverage enhancement for channels other than PUSCH and PUCCH Ericsson
14. R1-2006743 Potential techniques for coverage enhancement for channels other than PUSCH and PUCCH NTT DOCOMO, INC.
15. R1-2006822 Potential coverage enhancement techniques for other channels Qualcomm Incorporated
16. R1-2005724 Discussion on potential techniques for PUSCH coverage enhancement CATT
17. [R1-2005732](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005732.zip) Potential solutions for PUSCH coverage enhancements China Telecom
18. R1-2005758 Discussion on PUSCH coverage enhancement NEC
19. R1-2005889 Discussion on potential techniques for PUSCH coverage enhancement Intel Corporation
20. R1-2006531 On potential techniques for PUSCH coverage enhancement Apple
21. R1-2006579 PUSCH coverage enhancement Sharp
22. R1-2006613 PUSCH coverage enhancement Ericsson
23. R1-2006977 Potential coverage enhancement techniques for PUSCH Qualcomm Incorporated