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.* |

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.

# Proposals for GTW session(8/20)

***Proposal 1-1:******Study Msg3 PUSCH enhancement in NR coverage SI***

* ***Study at least Msg3 PUSCH repetition***
* ***FFS the aspects to be enhanced, e.g., signaling indication, repetition pattern and interplay between Msg1 and Msg3 etc.***
* ***FFS multiple-antenna techniques.***

***Proposal 1-2:******Study whether or how to enhance MsgA PUSCH in NR coverage SI***

* ***Study at least MsgA PUSCH repetition***
* ***FFS the aspects to be enhanced, e.g., signaling indication and repetition pattern etc.***
* ***FFS multiple-antenna techniques.***

***Proposal 2: Study whether/ how to enhance multiple PRACH transmissions in NR coverage SI.***

* ***FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc***

***Further updated Proposal 3:* Study whether/how to enable potential techniques forbeam refinement during initial access procedure and/or early CSI  during random access procedure.**

***Further updated Proposal 4: If PDCCH enhancement is needed, study PDCCH enhancement for NR coverage enhancement***

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

# 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. |
| Samsung | Generally we are supportive of this proposal except for the msgA PUSCH part.  Rel-16 2step RACH never targets coverage-limited UE, e.g., there is a SSB-RSRP threshold and, if a UE detects a SSB-RSRP lower than the threshold, the UE does 4step RACH. So we think msgA PUSCH is not applicable for coverage enhancements.  Also, the “***, e.g. the association with PRACH and PUSCH repetition type***” in 3rd sub-sub-bullet needs not to be emphasized and can be removed.  Regarding the proposal, it would be more appropriate to generally state the “FFS” part, e.g., “FFS the detailed aspects to be enhanced”.  ***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.*** |
| Intel | We share similar view as Samsung that we support coverage enhancement for Msg3 PUSCH, but it is not clear to us whether we need to consider coverage enhancement for MsgA PUSCH. In Rel-16 2-step RACH, RSRP based RACH type selection was defined for selection between 2-step RACH and 4-step RACH. When RSRP is greater than a threshold, 2-step RACH is used. Based on this, 2-step RACH is mainly targeted for cell center UE, where coverage is not an issue. Hence, in our view, coverage enhancement on MsgA including MsgA PRACH and PUSCH is not needed.  The updated proposal from Samsung looks good to us. One additional comment is that we may need to remove whether or not in the first FFS.  ***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.*** |
| InterDigital | We support the proposal from the FL |
| vivo | We agree to study Msg3/MsgA PUSCH enhancement.  According to our evaluation results, Msg1, Msg3 PUSCH and MsgA cannot reach the coverage requirement. A common scheme should be designed to improve the coverage performance of above channels. |
| Qualcomm | Support the proposal |
| OPPO | Support |
| Apple | We support Msg3 enhancement, i.e., Msg3 repetition. But not sure the benefits of MsgA PUSCH repetition. As discussed in Rel.16 2-step RACH, RSRP threshold is configured for type 2 random access, normally, the 2-step RACH UE will not work at cell edge. If introducing the repetition for MsgA PUSCH, then 2-step UE could work at cell edge. But the semi-statically reserved MsgA PUSCH is the concerns. The resource of msg3 is dynamically allocated by gNB, thus supporting msg3 repetition could not the issue. |
| SONY | Support the proposal. |
| Sharp | We support FL proposal. |
| Nokia/NSB | Similar to our comment to 2.1.2, we are not sure it is wise to list FFS points at this stage. The list may be understood as a conclusive set of issues/options which should be considered for the study. We believe we should leave it more open for now. For instance, as correctly captured by the FL, our position is that an interplay exists between coverage of msg3 and msg1, e.g., msg3 coverage at FR2 can be strongly impacted by the beam used by the UE, which in turn may be chosen according to the result of msg1 transmission, regardless of the number of repetitions, or PUSCH repetition type. We suggest removing the three FFS points in the first sub-bullet. |
| CMCC | We agree to study Msg3 PUSCH enhancements in this SI. |
| Panasonic | We share the Apple’s view. In order to manage limited TU, to focus on Msg.3 transmission would be possibility. |
| ZTE | Support to study Msg3 PUSCH and open to study MsgA PUSCH. |
| Ericsson | Support the spirit of the proposal but can we instead say “- Studymultiple-antenna techniques” as we expect this has potential to increase Msg3/MsgA PUSCH power?  Regarding the MsgA PUSCH, the target of 2-step RACH is for all cell sizes and since MsgA PUSCH of different UEs may be on same PUSCH occasion and even with same DMRS, compared to Msg3 PUSCH, MsgA PUSCH may also need be enhanced. Note that the RSRP threshold is configurable which can be low and it will not be configured for 2-step RACH only operation, i.e. when 4-step RACH is not supported. |
| Huawei, Hisilicon | * Support to study Msg3 PUSCH repetition, including repetition number, repetition pattern, and the corresponding signaling indication. * For the signaling indication, the RAR UL grant and DCI format 0-0 for Msg3 PUSCH retransmission should be considered. * For the repetition type, the repetition type A and repetition type B can be considered as starting point. * Additionally, the joint channel estimation and the more flexible frequency hopping patterns associated with repetition can be studied. * For multiple-antenna techniques, the Tx diversity may be an implementation issue. The standard impacts need to be identified first. |

### 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.*** |
| Samsung | First, similar to the above comments, msgA PRACH does not need to be applicable for PRACH enhancements.  Second, using “multiple msg.1 transmission” is better than “PRACH repetition”. The simulation results in FR1 show that PRACH is not coverage limited, while coverage limitation may happen more often in FR2. So, FR2 may be prioritized. Then, a target can be to enhance beam forming gain and a restriction to apply a same preamble for all the multiple msg.1 transmission should be avoided, at least for now.  Third, as also discussed in Tdocs and the FL summary, there are many aspects to be considered in this part (compared to the ones listed) and it is better to not have an exhaustive list. Thus we prefer a more general way for the FFS part as suggested below:  ***Proposal 2: Study multiple msg.1 transmission for NR coverage enhancement.***   * ***FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions and the transmission pattern design etc.*** * ***~~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.~~*** |
| Intel | We share similar view as CATT that we do not see strong need for PRACH coverage enhancement. Based on our link budget analysis in FR1 and FR2, if proper PRACH format is selected, coverage enhancement on PRACH seems not needed.  So we do not support this proposal. |
| InterDigital | We support the proposal from the FL |
| vivo | We agree with this proposal. According to our evaluation results PRACH is one of the bottleneck channels. |
| Qualcomm | Support the proposal |
| OPPO | We support PRACH repetition, at least for FR2. |
| Apple | We support the FL’s proposal |
| SONY | Support the proposal.  We expect a small number of repetitions may be applied for the PRACH transmission. We need to investigate the repetition pattern (by considering the possibility to re-use the legacy PRACH resources, and allocation of new resources to support repetition). |
| Sharp | PRACH repetition with different UL Tx beam may reduce latency in random access procedure. However, it doesn’t enhance the coverage. If we consider PRACH repetition, we should focus on PRACH with same beam. In addition, many companies observe that PUSCH/PUCCH is the coverage bottle neck. We should wait for more evaluation data to justify enhancement to PRACH. |
| Nokia/NSB | We are favorable to the principle underlying this proposal. If we understand the figure correctly, in Figure 2(a) UE sweeps its UL Tx beams during msg1 repetition, whereas a “simple” repetition is performed in Figure 2(b). If this is indeed the intention of the Figure, the goal may be different in the two cases, technically speaking:   1. Sweeping Tx beams during msg1 repetition may aim at finding the best possible Tx/Rx beam pair, i.e., the best Tx beam at the UE for a given Rx beam at gNB. 2. Repeating msg1 using the same beam may aim at reducing the SINR at which gNB can decode msg1.   In both cases, msg1 coverage could be enhanced. However, the possible resulting procedures, and corresponding gNB behaviors, could be very different in the two cases. Furthermore, the actual coverage enhancement potential could be very different as well, especially at FR2.  Given these observations, we are not sure that listing FFS points at this stage is the best course of action, since it may limit the scope of the study to very specific directions and miss the big picture. Indeed, we do acknowledge the potential of this proposal and we think that keeping it simple may be the best course of action for now. Hence, we propose to remove the FFS points and the Note.  Finally, albeit not a critical issue for us, we are not sure we should use the phrasing “PRACH repetitions”, given that it may be understood in different ways and create ambiguities. Samsung proposes to use “multiple msg1 transmissions” instead. If the intention is to describe a more general concept in which multiple msg1 transmissions are performed by UE, considering aspects such as the content of msg1, the approach to beam selection and so on as subjects of the study, then it would seem a good way to go to us. Moreover, if an FFS point is still retained, then we should probably write it as “***FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc.***” to better capture the spirit of Figure 2. |
| Panasonic | We share the similar view as CATT and Intel. |
| ZTE | We support the proposal and also fine with the modifications above to make it more general. |
| Ericsson | Not support.  We do not see the performance issue in the link budget study for PRACH which can also do reattempt with power ramping. We do not even understand why PRACH enh. is put in the high priority group. |
| Huawei, Hisilicon | PRACH can be retransmitted if failed, and the performance should be evaluated considering the retransmission. It is needed to further identify whether the PRACH is the bottleneck. |

## 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 |
| Samsung | Generally we are fine with the proposal.  One comment is that the previous msg.1/3 enhancements already contain aspects of beam refinement.  Another comment is, given a majority view that finer beam should be applied to improve the beam forming gain, an “e.g.,” part can be added in the following. Moreover, it is also important for the gNB and the UE to have a same understanding of (at least) the transmit beam from the UE in order to facilitate a valid beam pair.  With one possibility that we may make more progress, we can remove the “whether/”.  ***Proposal 3: Study how to enable potential techniques for beam refinement during random access procedure, e.g., finer beam measurement and reporting, and have a same understanding between gNB and UE of the UE tx beam.*** |
| Intel | We understand that the beam refinement is beneficial to improve the link budget for Msg4 PDSCH. However, our view is that before we make any suggestion for study on beam refinement, we need to first understand whether Msg4 is the performance bottleneck.  Another clarification for the proposal: it is unclear to us whether coverage enhancement SI/WI would be a right place to study beam refinement during RACH procedure. Given that it is closely related to beam management, it seems more appropriate to study/discuss beam refinement under FeMIMO. |
| InterDigital | We support the proposal from the FL |
| vivo | The evaluation methodologies of different beam refinement schemes should be discussed before the beam refinement is adopted in the initial access procedure. There are no evaluation results showing the performance gain of beam refinement.  In our opinion, the scheme of improving SSB beams should be studied carefully considering coexistence of Rel 15/16 UE and Rel 17 UE. The proper beam/CSI indication could provide an extra performance gain for Msg4, however the coverage of Msg4 is not the bottleneck in the evaluation results. Therefore, we suggest that the beam refinement scheme should be designed to enhance the performance of the bottleneck channel if the performance gain is justified through evaluation. |
| Qualcomm | Support the proposal |
| OPPO | We are OK with the proposal. |
| Apple | We are OK with the proposal. |
| Sharp | Many companies observe that PUSCH/PUCCH is the coverage bottle neck. We should wait for more evaluation data to justify enhancement to beam refinement in initial access. |
| Nokia/NSB | Support the proposal. |
| Panasonic | We are OK with the proposal. |
| ZTE | Support the proposal. Our view is beam management during initial access was not discussed in MIMO in Rel-15/16, and also not in the scope of Rel-17 MIMO. Since it impacts a lot on the coverage of channels during initial access, we suggest discussing here. |
| Ericsson | We agree to study how to improve the random access channels via beam refinement or early link quality report, given early CSI request bit is already in the RAR, though reserved in the spec.  To minimize the workload, simply reporting the best SSB in Msg3/MsgA PUSCH will help gNB to realize the best SSB beam given in initial access the selected SSB is only one of the SSBs that have RSRP above the RSRP threshold.  Our proposal is to update the proposal as below to since early CSI may not only for beam refinement:  ***Proposal 3: Study whether/how to enable potential techniques for early CSI and/or beam refinement during random access procedure.*** |
| Huawei, Hisilicon | Support the moderator’s proposal. |

### 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~~.*** |
| Samsung | We are generally fine with FL’s proposal.  One comment is that “repetition” is interpreted broadly to include all domains (time/frequency/spatial) and also include the possibility for CCE aggregation levels larger than 16 CCEs. |
| Intel | Before we make any suggestion for study on PDCCH enhancement, we need to first understand whether PDCCH is the performance bottleneck. At least based on our link budget analysis, we do not see the need for PDCCH coverage enhancement.  So we do not support this proposal. |
| NTT DOCOMO | We support the FL proposal. |
| InterDigital | We support the proposal from the FL |
| vivo | According to our evaluation results, downlink channels, including PDCCH, are not the limiting channels. There is no need to study PDCCH enhancement in CE SI.  It is widely accepted that the coverage of RedCap UE is inferior to that of the normal UE, especially for downlink channels. If UE specific PDCCH or broadcast PDCCH cannot satisfy the coverage requirement, RedCap UE would suffer from a much worse coverage. We suggest to consider PDCCH enhancements in RedCap SI. |
| Qualcomm | We think the emphasis should be on broadcast/RACH, because unicast PDCCH does not have much coverage issues in most scenarios. We suggest the following change to the proposal:  ***Proposal 4: Study PDCCH enhancement for NR coverage enhancement, at least for broadcast/RACH.***   * ***For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.*** * ***Study at least PDCCH repetition.*** * ***FFS other enhancements.*** |
| OPPO | We support the FL proposal. |
| Apple | We are OK with the proposal. |
| Sharp | Many companies observe that PUSCH/PUCCH is the coverage bottle neck. We should wait for more evaluation data to justify enhancement to PDCCH. |
| Nokia/NSB | According to our reading of the contributions, there seems to be a very large consensus among companies that UL channels are the most likely candidates for being coverage bottlenecks in NR, and among those PUSCH is the weakest link of the chain. DL channels never seem to display show-stopper problems. We have serious concerns about spreading efforts in multiple directions without considering the effectiveness of what we do in the limited number of TUs we still have before the end of the SI. A rationalization and prioritization is in order from our perspective.  Additionally, we agree with vivo on the comment related RedCap devices. That would seem a more sensible course of action. |
| Panasonic | We are OK with the proposal. |
| ZTE | Support the proposal. |
| Ericsson | We have not yet seen a bottleneck of PDCCH channel in random access given we already can have AL with 16 CCEs, precoder cycling, interleaved CCE to REG mapping etc.  Considering that we’ve already have proposal for beam refinement and early CSI report in previous section which can also improve the PDCCH as well though PDCCH may not be that necessary to be enhanced according to our link budget study, this proposal is not needed. |
| Huawei, Hisilicon | We don’t see a bottleneck of PDCCH channel for coverage yet. Considering limited TU for this topic, we prefer not to rush into the proposal. |

## 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. |
| Samsung | We are fine with the FL’s proposal. We understand that the sub-bullets are intended only as examples. |
| Intel | Before we make any suggestion for study on PDSCH enhancement, we need to first understand whether PDSCH is the performance bottleneck. At least based on our link budget analysis, we do not see the need for PDSCH coverage enhancement.  So we do not support this proposal. |
| vivo | PDSCH is not the bottleneck channel. Same comment as in section 2.2.2. |
| OPPO | Actually we don’t recognize the necessity of enhancing PDSCH so far. |
| Apple | If companies have the concerns, the study can be starting after evulation. |
| Sharp | Many companies observe that PUSCH/PUCCH is the coverage bottle neck. We should wait for more evaluation data to justify enhancement to PDSCH. |
| Nokia/NSB | According to most evaluations, PDSCH is not a bottleneck. We are not supportive of this proposal. Same additional comments made for 2.2.2 apply. |
| ZTE | Our simulation results show Msg4 PDSCH could have coverage issues in some scenarios. This is mainly due to limited beam gain and lower transmitting power with a small number of RBs. But we are open to study after more stable evaluation results available. |
| Ericsson | Not clear on the bottleneck of regular PDSCH. It might be good to check broadcasting channels, e.g. Msg4 PDSCH especially when the SSB is not the best one, but this has been covered in section 2.2.1 for early beam refinement.  We do not need this proposal right now but can be open to discuss the evaluations to see if there’s a need identified in bottleneck discussions and if there’re gains from new mechanisms. |
| Huawei, Hisilicon | Based on our evaluation results, PDSCH is not the bottleneck and to the motivation for enhancing should be clarified. |

## 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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# Updated proposal (first round)

Based on the first round of email discussion, the updated proposals are summarized as follows:

***Proposal 1-1:******Study Msg3 PUSCH enhancement in NR coverage SI***

* ***Study at least Msg3 PUSCH repetition***
* ***FFS the aspects to be enhanced, e.g., signaling indication, repetition pattern and interplay between Msg1 and Msg3 etc.***
* ***FFS multiple-antenna techniques.***

***Proposal 1-2:******Study whether or how to enhance MsgA PUSCH in NR coverage SI***

* ***Study at least MsgA PUSCH repetition***
* ***FFS the aspects to be enhanced, e.g., signaling indication and repetition pattern etc.***
* ***FFS multiple-antenna techniques.***

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| **Companies** | **Comments** |
|  | **FL observation/view on Proposal 1-1/1-2:**  All companies support to study Msg3 PUSCH enhancement. Majority companies support or ok to also consider Msg A PUSCH enhancement, while several companies don’t see the necessity on enhancing Msg A PUSCH. So, I made a separate proposal for Msg A.  Regarding the FFS points under the first sub-bullet, I revised a bit to be more general. As for multiple-antenna techniques, let’s keep it FFS for now since there are both proponents and opponents right now. |
| Ericsson | Fine. |
| Intel | We are fine with Proposal 1-1. Minor comment: “***Study Msg3 PUSCH enhancement in NR coverage SI***” needs to be changed to “***Study Msg3 PUSCH enhancement in NR coverage enhancement SI***”. This also applies for other proposals.  For Proposal 1-2, it is still unclear to us why we need to enhance the MsgA PUSCH given that 2-step RACH is targeted for cell center UEs, which do not have coverage issues.  However, for the sake of progress, we can accept to study whether/how to enhance MsgA PUSCH, but it is too early to put details under the main bullet. We suggest to update the proposal as follows:  ***Proposal 1-2:******Study whether or how to enhance MsgA PUSCH in NR coverage enhancement SI***   * ***~~Study at least MsgA PUSCH repetition~~*** * ***~~FFS the aspects to be enhanced, e.g., signaling indication and repetition pattern etc.~~*** * ***~~FFS multiple-antenna techniques.~~*** |
| Huawei, Hisilicon | DM-RS enhancements are proposed to be studied in PUSCH coverage enhancements. Part of solutions for DM-RS enhancements could be reused to improve Msg3 PUSCH coverage, e.g. cross-slot channel estimation/cross-repetition channel estimation when repetition is considered.  ***Proposal 1-1:******Study Msg3 PUSCH enhancement in NR coverage SI***   * ***Study at least Msg3 PUSCH repetition*** * ***FFS the aspects to be enhanced, e.g., signaling indication, repetition pattern ,interplay between Msg1 and Msg3, DM-RS enhancements related to repetition etc.*** * ***FFS multiple-antenna techniques.*** |
| CATT | Support |

***Proposal 2: Study whether/ how to enhance multiple PRACH transmissions in NR coverage SI.***

* ***FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc***

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| **Companies** | **Comments** |
|  | **FL observation/view on Proposal 2:**  Majority companies support to enhance PRACH while several companies don’t see strong need for enhancement.  FL’s view is to modify the proposal to be more general at this stage. |
| Ericsson | We propose to remove the bullet at this stage and focus on the “whether” instead. It’s not clear what is the “multiple” PRACH transmission, so we propose to remove “multiple” as well.  ***Proposal 2: Study whether~~/ how~~ to enhance ~~multiple~~ PRACH transmissions in NR coverage SI.***   * ***~~FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc~~*** |
|  | FL’s view: It should be clear among companies about what 'multiple' PRACH transmission is. Basically, it means the UE can transmit multiple PRACHs with the same or different beam with the same or different preamble before the end of a monitored RAR window. The benefit is also clear that it could be used to enhance the performance by e.g., repetition, or refine the beam pair by e.g. applying different beams for different transmissions so that gNB can determine a better beam for Msg2/3/4. This actually widely discussed in Rel-15 already also the contributions in this meeting. Given the majority companies show that PRACH could have coverage issues, I think it's fair to further study potential techniques. Otherwise your change would make the proposal meaningless since anyway whether enhancement is needed for all channels would be discussed in baseline evaluation agendas. So, I would strongly suggest you to re-consider since the current proposal is already a compromise based all comments from companies. |
|  | We can compromise to say “how” but the proposal isn’t clear with “multiple” in the main text.  Our understanding is that “enhance” should be to enhance what already specified in the spec., and the multiple PRACH is one of the options to enhance the existing PRACH transmissions, which is covered in the bullet as an example already.  So we can compromise to:  ***Proposal 2: Study whether/ how to enhance ~~multiple~~ PRACH transmissions in NR coverage SI according to if PRACH is the bottleneck.***   * ***FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc*** |
| Intel | As mentioned in our previous response, we do not see strong need to enhance the PRACH at least based on link budget analysis. We can accept to study how to enhance the PRACH transmission, but it is too early to put details in the sub-bullet. We suggest to update the proposal as  ***If PRACH is identified as a bottleneck, study ~~whether/~~ how to enhance ~~multiple~~ PRACH transmissions in NR coverage enhancement SI.***   * ***~~FFS the aspects to be enhanced, e.g., whether or how to enable the multiple transmissions, transmission pattern design, UE beam allocation, etc~~*** |
| Huawei, Hisilicon | Support Ericsson’s proposal. |
| CATT | We share the same views as Intel. Intel’s wording is more preferred from our side. |

***Proposal 3: Study whether/how to enable potential techniques for early CSI and/or beam refinement during initial access procedure.***

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| **Companies** | **Comments** |
|  | **FL observation/view on Proposal 3:**  Clear majority companies (13) support to consider techniques for beam refinement, while one company think the evaluation methodologies for beam refinement different beam refinement schemes should be discussed first, and two companies think the refined beam can only applied to Msg4 which is not the bottleneck.  FL’s view is that the current proposal doesn’t preclude discussion on the evaluation of techniques for beam refinement, and the refined beam can be applied to Msg2/3/4 depending on the techniques, e.g. using SSB or PRACH or Msg2 PDCCH for beam refinement for Msg3 PUSCH. |
| Ericsson | Since in CBRA and when UE is in RRC connected mode, gNB doesn’t know the UE is in connected or not connected mode based on the preamble, it’s better to use random access instead of initial access so we propose:  ***Proposal 3: Study whether/how to enable potential techniques for early CSI and/or beam refinement during ~~initial~~ random access procedure.*** |
|  | FL’s view: Some companies proposed to consider SSB related enhancement, that's why I made the change. But, to be clearer based on your comments, I made further update as follows. Hope it is acceptable for you.  Proposal 3: Study whether/how to enable potential techniques for beam refinement during initial access procedure and/or early CSI  during random access procedure. |
| Huawei, Hisilicon | Support FL’s proposal. |

***Further updated Proposal 3:* Study whether/how to enable potential techniques forbeam refinement during initial access procedure and/or early CSI  during random access procedure.**

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| **Companies** | **Comments** |
| Ericsson | Even for beam refinement, in RRC connected mode, if the TA timer expires, there may be no good beam selection, and also as we said, with CBRA, gNB doesn’t know which UE is connected or not and can only rely on the SSB beam mapped to the PRACH for msg2 transmissions. |
| Intel | We are fine with updated proposal. |
| Huawei, Hisilicon | Fine |
| CATT | Fine |

***Proposal 4: If PDCCH has coverage issues based on evaluation, study PDCCH enhancement for NR coverage enhancement***

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

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| **Companies** | **Comments** |
|  | **FL observation/view on Proposal 4:**  Majority companies support to enhance PDCCH while several companies don’t see strong need for enhancement.  FL’s view is to modify the proposal to be more general at this stage. |
| Ericsson | Change “If PDCCH has coverage issues based on evaluation,” to “If PDCCH is a coverage bottleneck based on evaluation based on evaluation”. |
|  | FL’s view: I am afraid changing to 'a coverage bottleneck' may be too strong. For instance, if we define the target as an absolute value, e.g., MPL or MCL, it is possible multiple channels need to be enhanced even though there is only one bottleneck channel. Even we use relative approach, it doesn't mean we are always to choose only worst channel to enhance. But, to address your concern, I am planning to change 'If PDCCH has coverage issues based on evaluation' to 'if PDCCH enhancement is needed'. Hope it is acceptable for you since the original proposal is already a compromise from majority companies! |
| Ericsson | Fine. |
| Huawei, Hisilicon | Support FL’s proposal. |

***Further updated Proposal 4: If PDCCH enhancement is needed, study PDCCH enhancement for NR coverage enhancement***

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

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| **Companies** | **Comments** |
| Ericsson | Fine. |
| Intel | We are not sure what broadcast/RACH is for. Suggest to make it clear. Further, PDCCH repetition is only one solution to address the coverage issue. There could be other solutions, including compact DCI, large AL, etc. Suggest to leave details as FFS.  We suggest to update the proposal as follows:  ***If PDCCH is identified as a bottleneck, ~~enhancement is needed~~, study PDCCH enhancement for NR coverage enhancement***   * ***Study at least for broadcast~~/RACH~~ PDCCH***   + ***For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.***   + ***FFS potential enhancement techniques.*** * ***~~Study at least PDCCH repetition.~~*** * ***FFS unicast PDCCH*** * ***~~FFS other enhancements.~~*** |
| Huawei, Hisilicon | OK |
| CATT | In the first sub-bullet, why do we need capture RACH? We are talking about PDCCH and the only things related to PDCCH during PRACH already covered by CSS and USS. We proposed to remove RACH in the first sub-bullet. |

***Proposal 5: Further discuss the evaluation of PDSCH and discuss whether/how to enhance PDSCH in NR coverage SI.***

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| **Companies** | **Comments** |
|  | **FL observation/view on Proposal 5:**  Majority companies don’t show interests on PDSCH enhancement and prefer to wait for more evaluation on PDSCH. 2 companies mentioned Msg 4 could have potential coverage issues.  FL’s view is to further discuss the evaluation and possible enhancement for PDSCH. |
| Ericsson | Fine. |
| Intel | We are fine with the proposal, but it seems more like a conclusion. |
| Huawei, Hisilicon | Fine. |
| CATT | Fine. |

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