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

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

**Agenda item: 8.8.2.3**

**Title: [103-e-NR-CovEnh-06] 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 RAN1#102-e meeting, the potential enhancements for channels other than PUSCH and PUCCH were discussed [1] and the following agreements were reached.

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| Agreements:   * Study Msg3 PUSCH enhancement in NR coverage enhancement 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.   Agreements:   * Study whether or how to enhance MsgA PUSCH in NR coverage enhancement SI   Agreements:  If PRACH enhancement is needed, study it in NR coverage enhancement SI, e.g. multiple PRACH transmissions.  Agreements:  Study whether/how to enable potential techniques for early CSI and/or beam refinement for physical channels during initial/random access procedure.  Agreements:   * If PDCCH enhancement is needed based on evaluation, study PDCCH enhancement for NR coverage enhancement   + Study at least for broadcast PDCCH     - For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.   + FFS unicast PDCCH   + Study the aspects to be enhanced, e.g., PDCCH repetition.   Agreements:  Further discuss the evaluation of PDSCH and discuss whether/how to enhance PDSCH in NR coverage enhancement SI.  Agreements:  Enhancement to PUSCH scheduled by RAR UL grant will not consider the optimization specific for CFRA case in NR coverage SI.  Agreements:   * Capture the following structure in TR 38.830.   6.3 Coverage enhancements for channels other than PUSCH and PUCCH  6.3.1 Enhancements for Msg3 PUSCH  ~~6.3.2 Others~~   * Note: The above structure can be further updated by adding more sections under section 6.3 for other enhancements if justified. |

This contribution provides a summary of proposed enhancements in contributions submitted under AI 8.8.2.3.

# Discussion

## Msg3/MsgA PUSCH enhancements

In RAN1#102-e, it was agreed to study at least Msg3 PUSCH repetition in NR coverage enhancement SI. In [2, Huawei, HiSilicon], [3, vivo], [4, ZTE], [5, CATT], [7, Intel], [8, China Telecom], [[9, CMCC], [10, NEC], [11, Samsung], [12, OPPO], [15, Sharp], [16, LG Electronics], [17, Ericsson], [18, Apple], [19, InterDigital], [20, NTT DOCOMO], [21, Qualcomm], [22, Nokia], [23, Potevio] and [24, WILUS], totally 20 companies show their interests on Msg3 enhancements and provide further analysis on potential enhancements aspects.

In the following, enhancements aspects are summarized for Msg3/MsgA PUSCH enhancements.

### Aspect 1: Performance evaluation on Msg3 repetition

There are 6 companies provide evaluation results for Msg3 repetition, and the observations are summarized as follows.

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| * [2, Huawei, HiSilicon]: About 2 dB gain can be obtained by doubling Msg3 repetition times at 10% BLER, 6 dB gain can be obtained by 8 repetitions. * [4, ZTE]: About 2.4~2.6 dB and 4.7~5.2 dB gain can be obtained by employing 2 repetitions and 4 repetitions respectively. * [7, Intel]: ~2 dB performance gain can be observed when the repetition level for Msg3 PUSCH is doubled. * [9, CMCC]: The 2 slot repetition could improve Msg 3 PUSCH coverage about 2.25 dB. * [17, Ericsson]: A gain of around 5.8 dB can be achieved for Msg3 with 8 repetitions. * [22, Nokia]: About 1.9 dB, 2.8 dB, 2.1 dB gain for 2, 4 and 8 repetitions respectively at 10% BLER in 4GHz urban scenario, and about 1.3 dB, 1.4 dB, 1.6 dB gain for 2, 4 and 8 repetitions respectively at 10% BLER in 28GHz urban scenario. |

Based on the evaluation results from companies above, which are basically aligned, the following observation is made.

***Observation 1: For Msg3 repetition, about 2 dB gain can be obtained at 10% BLER if the number of repetitions is doubled.***

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| **Company** | **Comments** |
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### Aspect 2: Indication of the number of repetitions for Msg3

**Indication of the number of repetitions for Msg3 initial transmission**

For Msg3 initial transmission, it can be scheduled by RAR UL grant or fallbackRAR UL grant. Based on companies’ input, the following options are proposed for indication of the number of repetitions for Msg3 initial transmission.

* Option 1: RAR UL grant or fallbackRAR UL grant
  + [2, Huawei, HiSilicon], [3, vivo], [5, CATT], [7, Intel], [8, China Telecom], [11, Samsung], [12, OPPO], [18, Apple], [23, Potevio]
* Option 2: DCI format 1\_0 with CRC scrambled by RA-RNTI
  + [3, vivo], [8, China Telecom], [11, Samsung], [18, Apple]
* Option 3: Implicit method, e.g, implicitly determined by PRACH configuration or information carried by RAR.
  + [2, Huawei, HiSilicon], [3, vivo], [5, CATT], [15, Sharp]
* Option 4: SIB1
  + [8, China Telecom], [11, Samsung], [24, WILUS]

It is also possible to consider some combined signaling, e.g., [11, Samsung] and [3, vivo] mention that a set of candidate values can be configured by system information, and RAR UL grant or DCI format 1\_0 with CRC scrambled by RA-RNTI can indicate further information for actual number of repetitions. In [24, WILUS], it proposes to consider enabling of Msg3 repetition and activation of Msg3 repetition.

Based on above summary, FL suggests to discuss the following proposal.

***Proposal 1: Study the indication of the number of repetitions for Msg3 initial transmission, including at least following options.***

* + ***Option 1: RAR UL grant or fallbackRAR UL grant***
  + ***Option 2: DCI format 1\_0 with CRC scrambled by RA-RNTI***
  + ***Option 3: Implicit method.***
  + ***Option 4: SIB1***

***Note: signaling indication with combined options is not precluded.***

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| **Company** | **Comments** |
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**Indication of the number of repetitions for Msg3 re-transmission**

For Msg3 re-transmission, it is scheduled by DCI format 0\_0 scrambled by TC-RNTI. Based on companies’ input, the following options are raised for indication of the number of repetitions for Msg3 re-transmission.

* Option 1: DCI format 0\_0 with CRC scrambled by TC-RNTI.
  + [3, vivo], [4, ZTE], [7, Intel], [12, OPPO]
* Option 2: Implicit method. E.g., the repetition factor is implicitly determined by Msg3 initial transmission.
  + [4, ZTE]

Based on above summary, FL suggests to discuss the following proposal.

***Proposal 2: Study the indication of the number of repetitions for Msg3 re-transmission, including at least following options.***

* + ***Option 1: DCI format 0\_0 with CRC scrambled by TC-RNTI.***
  + ***Option 2: Implicit method.***

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| **Company** | **Comments** |
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### Aspect 3: Support of repetition Type A or/and repetition Type B

In NR up to Rel-16, PUSCH repetition Type A and repetition Type B are supported for RRC connected mode UE. For Msg3 PUSCH repetition, the following options are proposed for supported repetition type.

* Option 1: Support both PUSCH repetition Type A and repetition Type B.
  + [2, Huawei, HiSilicon], [3, vivo], [4, ZTE], [15, Sharp], [23, Potevio]
* Option 2: Support PUSCH repetition Type A only.
  + [7, Intel], [11, Samsung]

FL’s suggestion is not to down-select one option at this stage, and propose to discuss the following proposal.

***Proposal 3: Study the repetition type for Msg3 PUSCH repetition.***

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| **Company** | **Comments** |
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### Aspect 4: Study the feasibility and applicability of normal PUSCH enhancements (if supported) for Msg3 PUSCH initial/re-transmission

In AI 8.8.2.1, enhancements to normal PUSCH has been discussing, including aspects such as time domain enhancements, frequency domain enhancement, DM-RS enhancements and power domain enhancements.

As discussed in [2, Huawei, HiSilicon], [4, ZTE], [8, China Telecom], [9, CMCC], [17, Ericsson], [19, InterDigital] , [23, Potevio], **cross-slot channel estimation/DMRS bundling can be studied for Msg3 PUSCH**. Simulation results are also provided in [4, ZTE], [9, CMCC], and the following observations are derived.

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| [4, ZTE]: Msg3 PUSCH repetition with cross-slot channel estimation can provide 0.5dB~ 1.07dB performance improvement in urban scenario.  [9, CMCC]: The 2 slot repetition could improve Msg 3 PUSCH coverage about 2.25dB. And the cross channel estimation could provide additional 1.75dB gain based on 2 slot repetition. |

More generally, it is proposed in [4, ZTE], [8, China Telecom] that techniques for normal PUSCH enhancements, including time domain enhancements, frequency domain enhancement and DM-RS enhancements, can be studied for Msg3 PUSCH enhancement. In [11, Samsung], it proposes that the applicability of solutions for coverage enhancements of ‘normal’ PUSCH to Msg3 PUSCH should be separately considered for each solution. [22, Nokia] proposes to study solutions to reduce the difference between RRC-idle and RRC-connected PUSCH operations and performance, and study enhancement of the existing features of RRC-idle PUSCH, e.g., frequency hopping, if they provide evidence of a positive impact in terms of MCL/MIL/MPL.

Based on above summary, FL suggests to discuss the following proposals.

***Proposal 4-1: Study cross-slot channel estimation for Msg3 repetition.***

***Proposal 4-2: Study the feasibility and applicability of normal PUSCH enhancements (if supported in AI 8.8.2.1) for Msg3 PUSCH initial/re-transmission.***

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| **Company** | **Comments** |
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### Aspect 5: gNB identification of whether a UE supports Msg3 PUSCH enhancements or not

For legacy UE, Msg3 PUSCH repetition is not supported, while it has been agreed to study Msg3 PUSCH enhancements for Rel-17 NR coverage UE.

According to [4, ZTE], [5, CATT], [8, China Telecom], [10, NEC], if a Rel-17 UE supports Msg3 repetition and related enhancements, gNB needs to identify whether the UE supports Msg3 PUSCH enhancements or not before it indicates corresponding signaling e.g., the number of repetitions for Msg3 PUSCH.

More specifically, [8, China Telecom] proposes that whether a UE supports Msg3 repetition or not can be implicitly indicated, e.g. different ROs or different preamble sequences. Similarly in [10, NEC], it proposes that special PRACH resources and/or preamble for msg3 repetition enhanced UE should be configured by gNB broadcasting.

Based on above summary, FL suggests to discuss the following proposal.

***Proposal 5: Study solutions for gNB to identify whether a UE supports Msg 3 PUSCH enhancements or not.***

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| **Company** | **Comments** |
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### Aspect 6: Support of MsgA PUSCH repetition

In RAN1#102-e, the following agreements were reached for MsgA PUSCH enhancement.

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| Agreements:   * Study whether or how to enhance MsgA PUSCH in NR coverage enhancement SI |

For 2-step RACH, an RSRP threshold is configured, and a UE selects 2-step random access type to perform random access based on this threshold. Based on companies’ input, the support of MsgA PUSCH repetition is summarized as follows.

* **Alt. 1: Support MsgA PUSCH repetition** 
  + [14, Sony], [12, OPPO]?
  + Main reasons are:
    - The configurable RSRP threshold allows the network to steer cell-centre UEs towards using 2-step RACH and cell-edge UEs to use 4-step RACH, the setting of the threshold value is down to network implementation and a network can set the threshold low such that all UEs use 2-step RACH.
    - RAN1 should look to enhance the coverage of channels whose Rel-16 coverage is worse rather than those Rel-16 channels that already have good coverage.
* **Alt. 2: Do not support MsgA PUSCH repetition** 
  + [7, Intel], [15, Sharp], [18, Apple]
  + Main reasons are:
    - RSRP based RACH type selection mechanism was defined for selection between 2-step RACH and 4-step RACH. More specifically, when measured RSRP is greater than a threshold, 2-step RACH is used for RACH procedure. Based on this, it is evident that 2-step RACH is mainly targeted to UEs in good channel conditions, where coverage enhancement is not needed.
    - If the UE has the coverage issue, it will not select the 2-step RACH, otherwise access failure and falling back to 4-step RACH will increase the access delay and occupy the MsgA PUSCH resource.
    - If the MsgA PUSCH coverage enhancement is supported, the MsgA PUSCH repetition or hopping would require more resources reserved, and these resources are hard to be shared with Rel.16 2-step RACH UE.
    - More repetitions could increase the access delay.

Based on above summary, FL suggests to discuss the following proposals.

***Proposal 6: MsgA PUSCH repetition can be studied with low priority.***

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| **Company** | **Comments** |
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### Other aspects for Msg3 enhancements

**Multiple antenna techniques**

In [11, Samsung], it notes that the msg3 spatial setting is left to UE implementation and refinement of spatial setting from msg1 tx to msg3 tx was not finalized in NR Rel-15. In NR Rel-16 2-step RACH, the PRACH and msgA PUSCH are specified to use a same spatial setting. It proposes to **specify that a same spatial setting applies for PRACH preamble and corresponding msg3 PUSCH transmissions**.

In NR up to Rel-16, Msg3 PUSCH transmission, which is scheduled by DCI format 0\_0, is based on a single antenna port. In [17, Ericsson], it observes that **open-loop Tx Diversity together with Msg3 repetition** can improve Msg3 coverage through diversity gain and Tx chain power combining, and **closed-loop Tx Diversity for Msg3** can benefit from coherent combining or antenna selection as well as Tx chain power combining.

**Waveform of Msg3**

In [6, Indian Institute of Tech (H)], it observes that UL transmission can benefit from power boosting wherein the max transmission power can reach up to 26dBm or 29dBm based on the UL duty cycle when DFT-s-OFDM waveform with pi/2 BPSK modulation is used. Every dB gained in transmission power significantly enhances the coverage of the UE. **Thus, pi/2 BPSK waveform with spectrum shaping is proposed for Msg3 transmission.**

**Power domain consideration for Msg3**

In [11, Samsung], it finds UEs in different conditions may experience better msg3 reception reliability using different values of power adaptation parameters (e.g., power ramping step powerRampingStep and pathloss compensation factor msg3-Alpha) . It can be beneficial from a latency perspective to use a suitable set of power adaptation parameters which can, e.g., faster achieve higher transmission powers in fewer number of retransmissions. **Thus, it proposes to consider multiple sets of power adaptation parameters for msg3 PUSCH coverage enhancement.**

**Inter-slot frequency hopping for Msg3 repetition**

In [18, Apple], it observes the inter-slot frequency with the repetition can provide 2dB performance gain. This gain is worthwhile to specify inter-slot frequency hopping and time domain repetition for Msg3 PUSCH coverage enhancement. Thus, it proposes **Msg3 repetition with inter-slot frequency hopping are supported.**

**More inputs regarding to above four aspects are needed. FL proposal will be provided after collecting more views from companies.**

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| **Company** | **Comments** |
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## PRACH enhancements

### Necessity of PRACH enhancement

In [2, Huawei, HiSilicon], [3, vivo], [4, ZTE], [5, CATT], [7, Intel], [11, Samsung], [12, OPPO], , [14, Sony], [15, Sharp], [16, LG Electronics], [19, InterDigital], [22, Nokia], PRACH enhancement is discussed and views on the necessity of enhancement are summarized as follows.

* **Alt. 1: Support PRACH enhancement** 
  + [2, Huawei, HiSilicon], [3, vivo](lower priority), [4, ZTE], [7, Intel], [11, Samsung], [12, OPPO], [14, Sony], [19, InterDigital], [21, Qualcomm], [22, Nokia], [23, Potevio]?
  + Main reasons are:
    - Most of proponents find that the PRACH link performance is worse than the target performance in many scenarios, and enhancement to PRACH itself is needed.
    - PRACH repetition can provide significant MIL/MPL gains for msg1, and it allows UE to enjoy larger antenna array gain for both msg1 and msg3 when Tx sweeping is used for multiple PRACH transmissions.
    - UE can benefit from full antenna array gain only if the angular direction to steer the TX beam used for transmission is known. Acquiring reliably this information in the current random-access procedure, i.e., during RRC-idle operations, is not guaranteed.
    - Transmitting PRACH re-attempts with different beams incurs long latency for initial access and it would increase the possibility that the SSB the UE selected does not remain the “best” SSB, for example due to UE mobility. In other words, it allows that a UE without beam-correspondence capability may transmit multiple PRACH preambles using multiple different UE Tx beams in a more timely manner. This can provide more UL beam gain and reducing RACH preamble re-transmission.
    - Based on the typical TDD configuration, there might be only one or two consecutive UL slots. This will limit the usage of long PRACH format and lead to coverage issue based on short PRACH format transmission.
* **Alt. 2: No need for PRACH enhancement** 
  + [5, CATT], [15, Sharp], [16, LG Electronics]?, [17, Ericsson]?
    - One company ([5, CATT]) observes that the performance of PRACH format B4 is much better than the target performance in terms of MPL.
    - In Rel-15/16, UE can sweep the transmission beam when UE tries RACH preamble re-transmission, wherein a proper transmitting beam can be applied at the UE side.
    - PRACH collision rate between UE support MSG1 repetition and legacy UEs would increase when more PRACH preambles are transmitted per RACH attempt.
    - For multiple PRACH transmission for beam refinement, it observes higher PRACH collision rate, higher interference level on PRACH resources and measurement accuracy cannot be guaranteed.
    - There are abundant PRACH formats which are defined for different deployment and coverage in the current specification, e.g. PRACH format 4 is defined for coverage enhancement. It is an implementation issue for network to select a proper TDD UL DL configuration which supports a PRACH format targeting to a large coverage.
    - The benefit of PRACH enhancement for the enhancement of msg3 is not technically clear.

Based on above summary, FL suggests to discuss the following observation based on majority view.

***Observation 2: PRACH enhancement is needed in NR coverage enhancement SI.***

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| **Company** | **Comments** |
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### Multiple PRACH transmissions

Based on the input from proponents, there could be two ways for PRACH enhancements. Depending on the same or different beams used for each transmission, the two ways can be catheterized as ‘PRACH repetition’ and ‘PRACH beam sweeping’. An example is shown in Figure 1.



**Figure.1 - RO bundle for same Tx beam an different Tx beam [11, Samsung]**

**Evaluation results**

In [4, ZTE] and [22, Nokia], evaluation results for multiple PRACH transmissions are provided and have the following observations.

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| In [4, ZTE], it observes that, for PRACH repetition, about 1.7~3.7 dB and 3.7~5.2 dB gain can be obtained by employing 2 repetitions and 4 repetitions respectively. And PRACH sweeping transmission with 2 Tx beam can provide 2.5dB coverage improvement for channels in RACH procedure.  In [22, Nokia], it finds, by applying multiple PRACH transmissions, the MIL/MPL gap between SSB and msg1 transmission can be reduced to almost zero when UE max transmit power is 23 dBm, and more than halve the MIL/MPL gap when UE max transmit power is 12 dBm. It can achieve around 65% MIL/MPL gap reduction between SSB and msg3, irrespective of the UE max transmit power. |

Although limited simulation results are provided, it seems reasonable that multiple PRACH transmissions could provide performance gain also considering the deterministic analysis from majority companies. Thus, FL suggests to discuss the following observation.

***Observation 3: PRACH repetition can provide non-negligible performance gain, and multiple PRACH transmissions with beam sweeping allows UE to make use of the potential of multiple antenna NR technology in RRC-idle state to provide larger antenna array gain.***

**Considering the concerns from several companies, e.g., high collision rate causing by multiple PRACH transmissions, it would be fair and more efficient to discuss Observation 3 after there is consensus on Observation 2.**

**Spec impacts**

Based on the input from [2, Huawei, HiSilicon], [3, vivo], [4, ZTE], [7, Intel], [11, Samsung], [12, OPPO], [14, Sony], [21, Qualcomm], [22, Nokia], the spec impacts are summarized as follows.

* Determination of PRACH repetition.
* The number of repetitions, repetition pattern (e.g., time or frequency domain repetition).
* The applicability for FR1 and/or FR2, and applicability for short and/or long PRACH preamble format.
* The TX beam to be used for each initial transmission, e.g., same or different beam across the multiple msg1 transmissions, and finer beam for msg1 based on CSI-RS resources configured during initial access etc.
* If TX beam used for each msg1 transmission is different, how to let UE know which one should be used for the following steps for RACH procedure;
* gNB may need to be able to differentiate between enhanced UE and legacy UE.
* How to handle possible collisions between PRACH transmission with and without multiple msg1 transmissions.

**FL suggests to further discuss the potential spec impacts after there is conclusion on Observation 2 and 3.**

## PUCCH with Msg4 HARQ-ACK

In Rel-15/16, PUCCH repetition can only be configured via higher layer parameter PUCCH-Config which is unavailable during the initial random access.

In [4, ZTE], [15, Sharp], it observes that PUCCH carrying Msg4 HARQ-ACK may also encounter coverage issues in some scenarios. They both propose to study PUCCH repetition when a UE does not have dedicated PUCCH resource configuration.

In addition, simulation results are provided in [4, ZTE]. It observes that, for PUCCH carrying 1-bit HARQ-ACK for Msg4, about 3 dB and 6 dB gain can be obtained by employing 2 repetitions and 4 repetitions respectively.

In [5, CATT], it notes that it may need further study on whether coverage enhancement for PUCCH corresponding to Msg4 is needed or not.

Considering the necessity of enhancement highly depends on the outcome of sub-agenda 8.8.1, FL suggests to discuss the following proposal.

***Proposal 7: Contingent on the outcome of sub-agenda 8.8.1, study PUCCH repetition for PUCCH carrying HARQ-ACK for Msg4 in NR coverage enhancement SI.***

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| **Company** | **Comments** |
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## Beam refinement during initial/random access

In this section, solutions for beam refinement (**except for** multiple PRACH transmissions which is discussed in Section 2.2 and multiple PDCCH transmissions which is discussed in Section 2.6**)** during initial/random access procedure are summarized.

Based on companies’ input, the following solutions for beam refinement are raised.

* **Candidate solution 1: SSB enhancements** 
  + Support: [2, Huawei, HiSilicon], [4, ZTE], [14, Sony]
    - This could provide beam refinement for all channels in initial/random access procedure. Proposed solutions include time/frequency domain solutions to improve SS/PBCH performance, increasing the number of SSB beams, SSB polarization.
    - [4, ZTE] observes that increasing the number of SSBs from 4 to 8 at 700MHz can provide 1.84 dB performance gain, and the method for indicating candidate SSB index in Rel-16 NR-U can be reused for index indication of refined SSBs.
    - In [14, Sony], it observes that, between 25% and 40% of the times, a UE will make an erroneous beam selection if it is not aware of polarization properties.
  + Not support: [3, vivo], [5, CATT]
    - [3, vivo]: There is backward compatibility issue if the number of SSB beams is supported by simply extending the number of SSBs in a half frame.
    - [5, CATT]: The performance of PDSCH, PDCCH and SSB are much better than the target performance in terms of MPL.
* **Candidate solution 2:** Reporting the best SSB/alternative SSB beam/early CSI in Msg3 PUSCH.
  + Support: [11, Samsung], [13, AT&T], [16, LG Electronics], [17, Ericsson], [19, InterDigital], [21, Qualcomm].
    - This could provide beam refinement for Msg4 in random access procedure.
    - [11, Samsung]: By having finer beam reference signal, e.g., NZP CSI-RS resources, configured during initial access, a UE is able to refine a selected DL beam, and can be reported in Msg3.
    - [13, AT&T]: Beam adjustment using alternative beam reporting in Msg3 is beneficial for initial access coverage enhancement
    - [16, LG Electronics]: The possibility that the UE preferred SSB index could be changed after receiving msg2 PDCCH/PDSCH. If the benefit of DL Tx beam refinement is revealed clearly for DL coverage enhancement, we may consider to discuss a potential techniques for reporting UE preferred SSB index.
    - [17, Ericsson]: Maintaining PDSCH coverage without accurate CSI may require relatively high amounts of downlink resource; Msg4 PDSCH has worse coverage than other DL PDSCH; Early CSI availability can provide downlink coverage for small PDSCH packet sizes before normal CSI is available without excessive latency, RRC signalling overhead or excessive downlink resource.
    - [19, InterDigital]: Early CSI reporting would be beneficial for the selection of a proper MCS for msg4 PDSCH and subsequent PDSCH messages until the UE obtains a suitable CSI reporting configuration.
    - [21, Qualcomm]: Beam reporting by UE can be used simply as reporting a better SSB beam index, or selection of a refined beam for refinement of the SSB beam.
  + Not support: [3, vivo],
    - [3, vivo]: According to the evaluation results, Msg4 is robust enough for the required scenarios, hence there is on strong motivation to support early CSI report.

Based on above summary, FL suggests to discuss the following proposal based on majority view.

***Proposal 8: Study solutions for beam refinement during initial/random access, including at least beam reporting in Msg3 PUSCH.***

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| **Company** | **Comments** |
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## A-CSI enhancements

**A-CSI/SP-CSI in PUSCH**

In NR Rel-15/16, three types of CSI reporting, periodic CSI reporting (P-CSI), semi-persistent CSI reporting (SP-CSI) and aperiodic CSI reporting (A-CSI), were supported. Among them, P-CSI and SP-CSI can be transmitted on PUCCH. A-CSI and SP-CSI can be transmitted on PUSCH, but CSI on PUSCH cannot be repeated.

In [17, Ericsson], it proposes to support CSI repetition on PUSCH with repetition Type A or Type B, based on the following observations.

* CSI on PUSCH is one of the coverage bottlenecks and its coverage needs to be enhanced.
* A-CSI repetition on PUSCH has already been studied in NR release 15 and release 16 and can be a good baseline for its study in R17.
* Around 4 dB gain can be achieved with up to 8 repetitions of CSI (6+5 bits) on PUSCH for mid-band.
* The estimated maximum isotropic loss of CSI on PUSCH is worse than CSI on PUCCH, becoming one of the most limiting factors for cell coverage.

On the other hand, it is observed in [5, CATT] that, if A-CSI on PUSCH is problematic, UE can rely on P-CSI which will be certainly taken care of in PUCCH coverage enhancement. The motivation of coverage enhancement for A-CSI is not clear.

Based on above summary, FL suggests to discuss the following proposal, and a more constructive proposal will be provided after collecting more inputs from companies.

***Proposal 9: Further discuss whether to support CSI repetition in PUSCH in NR coverage enhancement SI.***

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| **Company** | **Comments** |
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**A-CSI on PUCCH**

In NR Rel-15, A-CSI can only be transmitted on PUSCH. In [17, Ericsson], it finds that the estimated maximum isotropic loss of CSI on PUSCH is around 3.5dB less than CSI on PUCCH without repetition, becoming one of the most limiting channels for cell coverage. However, the CSI coverage bottleneck can be resolved by the support of A-CSI on PUCCH. It proposes to continue investigation and evaluation of A-CSI on PUCCH in coverage enhancement topic, and then discuss in RAN#90-e to decide where specification of A-CSI on PUCCH will be, e.g. Rel-17 feMIMO or Rel-17 IIoT/URLLC.

Based on above, FL suggests to discuss the following proposal

***Proposal 10: Interested companies can continue investigation and evaluation of A-CSI on PUCCH in coverage enhancement topic.***

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| **Company** | **Comments** |
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## PDCCH enhancements

In [3, vivo], [4, ZTE], [5, CATT], [12, OPPO], [20, NTT DOCOMO], [19, InterDigital], [21, Qualcomm], PDCCH enhancement is discussed and companies’ views are summarized as follows.

* **Support PDCCH repetition at least for broadcast PDCCH**
  + Support: [4, ZTE], [12, OPPO], [19, InterDigital], [20, NTT DOCOMO], [21, Qualcomm]
    - [4, ZTE]: There still exists some scenarios that needs coverage enhancement for broadcast PDCCH based on link budget evaluation. Study compact DCI, PDCCH repetition and PDCCH-less mechanism.
    - [21, Qualcomm]: There is a 5.4dB gap between broadcast PDCCH to PUCCH format 3, so a small number of repetitions upto 4 is sufficient.
    - [19, InterDigital]: Study PDCCH enhancements for RAR relate to configuration of PDCCH repetitions and whether/how to provide indication of a best PDCCH repetition among a repetition bundle in msg3 or in early CSI report.
    - [20, NTT DOCOMO]: Study smaller DCI payload size and PDCCH repetition etc.
  + Not support: [3, vivo], [5, CATT]
    - [3, vivo]: Beam refinement based on PDCCH repetition may suffer from low measurement accuracy and higher power consumption.
    - [5, CATT]: The performance of PDCCH is much better than the target performance in terms of MPL.

**Evaluation results**

In [4, ZTE] and [21, Qualcomm], evaluation results for broadcast PDCCH repetition are provided and have the following observations.

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| [4, ZTE]: For PDCCH repetition, about 2.8~3.1 dB and 4~5.8 dB gain can be obtained by employing 2 repetitions and 4 repetitions respectively.  [21, Qualcomm]: For broadcast PDCCH, 2 repetition and 4 repetition yield 2dB and 4dB gain respectively. If DMRS bundling is considered, the gains are increased to 3dB and 6dB. |

Based on the evaluation results provided, FL suggests to discuss the following observation.

***Observation 4: For broadcast PDCCH, 2 repetitions and 4 repetitions yield about 2~3dB and 4~6dB gain respectively***

Companies are invite to provide more evaluation results.

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| **Company** | **Comments** |
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Based on above summary, it seems hard to make further progress on top of the agreements reached for PDCCH before.

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| Agreements:   * If PDCCH enhancement is needed based on evaluation, study PDCCH enhancement for NR coverage enhancement   + Study at least for broadcast PDCCH     - For broadcast PDCCH, it includes a PDCCH monitored in a Type0/0A/1/2-PDCCH CSS set.   + FFS unicast PDCCH   + Study the aspects to be enhanced, e.g., PDCCH repetition. |

**FL suggests to further discuss PDCCH related enhancements once the link budget evaluation results from sub-agenda 8.8.1 are more solid.**

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| **Company** | **Comments** |
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## Msg4 PDSCH

In this section, inputs on Msg4 PDSCH enhancements are summarized except for beam refinement related enhancements which is discussed in Section 2.4.

In [17, Ericsson], it noted that in NR up to Rel-16, 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 or for paging.

In [15, Sharp], it proposes that if enhancement to message 4 PDSCH is supported, scaling factor S can be applied to PDSCH scheduled by DCI format with TC-RNTI.

In [21, Qualcomm], it proposes that NR should support coverage enhancement of Msg4 PDSCH, e.g. via PDSCH repetition.

Based on above, FL suggests to discuss the following proposal.

***Proposal 11: Contingent on the outcome of sub-agenda 8.8.1, study Msg4 PDSCH enhancement in NR coverage enhancement SI.***

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| **Company** | **Comments** |
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## PDSCH enhancement

In [5, CATT], it observes that the performance of PDSCH is much better than the target performance in terms of MPL. However, in [20, NTT DOCOMO], it proposes that improvement of PDSCH may be considered, and potential techniques for PUSCH coverage enhancements can be also applied to PDSCH. In addition, PDSCH repetition for frequency domain can be one of the potential techniques.

Considering the limited interests and expected good link budget performance for PDSCH, FL suggests to discuss the following proposal.

***Proposal 12: PDSCH enhancement is not studied in NR coverage enhancement SI.***

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| **Company** | **Comments** |
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