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.

# Discussion (2nd week)

This section is to summarize the email discussion during the 2nd week of RAN1#102-e meeting.

FL suggestion is to further discuss more details for some topics that got relatively more interests/support from companies in the first week of discussion. In the following, companies are encouraged to provide your input on the questions/proposals from feature lead.

## Msg3/Msg A PUSCH enhancement

FL suggestion is that we will not make a hard decision on whether or not to support the FFS techniques in this meeting, i.e. multiple-antenna techniques or Msg A PUSCH. It might be fairer to let companies think more on this and bring proposals in the next meeting. But, it would be good to look into the FFS points for the supported Msg3 PUSCH repetition.

For CBRA, Msg3 PUSCH includes both Msg3 initial transmission scheduled by RAR UL grant and also Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by TC-RNTI. However, it seems we missed CFRA PUSCH scheduled by RAR UL grant and its re-transmission scheduled by DCI format 0\_0 scrambled by C-RNTI. PUSCH repetition is not supported for both CFRA PUSCH and it’s re-transmission. Though no companies propose to enhance CFRA PUSCH, it’s better to have some clarification.

1. **Q1: Do you think the enhancements to Msg3 initial PUSCH transmission scheduled by RAR UL grant should also apply to CFRA PUSCH scheduled by RAR UL grant?**

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| **Companies** | **Comments** |
| Ericsson | Yes.  The Msg3 repetition scheduled by RAR UL grant in Msg2 or scheduled by UL grant in fallback RAR in both CBRA and CFRA should be supported since it’s still Msg3.  For the Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by C-RNTI/TC-RNTI, they can follow the repetition configuration for the initial transmission or separately configured in the DCI, we can discuss further, or add a FFS here is also fine. |
| Samsung | Can be.  The exact design of msg.3 enhancement is not clear now. In general, it might be possible to apply to the CFRA PUSCH scheduled by RAR UL grant as well. We can discuss this in the future. |
| Sharp | No.  Msg3 definition in TS38.321 is as follows. Thus, msg3 doesn’t include a PUSCH scheduled by RAR UL grant for CFRA. We don’t see the benefit to enhance the PUSCH scheduled by RAR UL grant for CFRA since the random access procedure ends at reception of the RAR.  **Msg3**: Message transmitted on UL-SCH containing a C-RNTI MAC CE or CCCH SDU, submitted from upper layer and associated with the UE Contention Resolution Identity, as part of a Random Access procedure. |
| CATT | No. We don’t see the necessity to enhance CFRA.  First of all, CFRA is different from CBRA as the retransmission of msg 3 can be scheduled by a non-fallback DCI scrambling with C-RNTI, which means repetition is already supported from release 15. The coverage can be guaranteed by retransmission.  Furthermore, considering CBRA is already enhanced, it would be redundant to enhance CFRA. |
| vivo | NO  For CFRA, UE has RRC connection, the PUSCH repetition can be scheduled by a non-fallback DCI. It is not necessary to support PUSCH repetition scheduled by a fallback DCI, i.e. DCI format 0-0. |
| Intel | No  We do not think Msg3 repetition is needed for CFRA case. As commented by CATT, non-fallback DCI can be used to schedule Msg3 retransmission with C-RNTI if coverage is an issue. |
| Nokia/NSB | As far as we are concerned, the problem at hand is the coverage of a msg3 transmission. We should study how to solve the problem to meet the present and future needs for both FR1 and FR2, if only one solution suffices or if multiple solutions must be used in conjunction and so on. We can then discuss when such enhancements can be used, i.e., for which procedures in particular. On the other hand, if a decision must be taken, our answer as of now would be to focus on CBRA, first. Indeed, we are not convinced it is even 100% accurate to refer to “msg3” when we consider the very specific case of PUSCH scheduled by RAR UL in the context of CFRA. Further clarifications in this regard would be welcome. |
| Qualcomm | We think this can be discussed in future (because the design for Msg3 enhancement is not clear yet). |
| OPPO | CFRA PUSCH repetition can be revisited after the enhancement on CBRA PUSCH is clear. |
| Apple | We share the similar view as OPPO, we can start from CFRA msg3 repetition first. Then checking any further enhancement is needed for CFRA PUSCH repetition. |

1. **Q2: Do you think the enhancements to Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by TC-RNTI should also apply to** 
   1. **only CFRA PUSCH re-transmission scheduled by DCI format 0\_0 scrambled by C-RNTI?**
   2. **all PUSCH scheduled by DCI format 0\_0?**
   3. **neither a) nor b)**

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| **Companies** | **Comments** |
| Ericsson | a.).  We do not have to consider normal PUSCH here other than Msg3 PUSCH (initial or retransmission). |
| Samsung | c),  Again, the exact enhancement for msg.3 is not clear now. This aspect can be further studied.  For a), the PUSCH re-transmission in CFRA can be scheduled by DCI format 0\_1 scrambled with C-RNTI, not necessarily limited to DCI 0\_0. Moreover, this **CFRA PUSCH re-transmission** should be considered as normal PUSCH instead of other channels.  For b), the enhancement for normal PUSCH has already been discussed in other AI. |
| Sharp | a)  We do not see motivation to enhance PUSCH scheduled by fallback DCI. |
| CATT | C), don’t see any issue. |
| vivo | c)  Similar to the answer for the last question, the PUSCH repetition is not applicable for PUSCH scheduled by RAR UL grant and its retransmission for CFRA, non-fallback DCI can be used. |
| Intel | c) Share similar view as other companies. |
| Nokia/NSB | c), agree with Samsung |
| OPPO | c), Share similar view as Samsung |
| Apple | c), Share similar view as Samsung |

Below are some further detailed questions on the FFS points of Msg3 PUSCH enhancements. We may no need to rush into agreeing on the detailed solutions in this meeting. But it’s better to first collect all possible candidate solutions now.

**[L]Q3: What’s view on enhancements to PUSCH transmission scheduled by RAR UL grant, including**

* **Q3-1: How to enable the repetitions or how to indicate the number of repetitions, and any other indication?**
* **Q3-2: Do you think it needs to support both PUSCH repetition Type A and repetition Type B?**
* **Q3-3: Do you think the potential enhancements agreed in PUSCH agenda 8.8.2.1 should be also applied to PUSCH transmission scheduled by RAR UL grant?**
* **Q3-4: Any other comments?**

Note1: If the conclusion on Q1 is ‘No’, the PUSCH transmission scheduled by RAR UL grant here only includes Msg3 PUSCH.

Note2: The interplay between Msg1 and Msg3 is to be discussed in section 2.2.

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| **Companies** | **Comments** |
| IITH, Reliance Jio, IITM, CEWIT, Tejas Networks | Msg3 is the first UL channel after PRACH. While PRACH can support large cell sizes, the Msg3 PUSCH waveform CP-OFDM is severely limited. We must consider using DFT-s-OFDM waveform and pi/2 BPSK modulation for this transmission to significantly enhance its coverage. All enhancements related to pi/2 BPSK done for regular PUSCH must also be replicated for Msg3. |
| Ericsson | Indication of repetition factors can be in the RAR UL grant or fallback RAR UL grant.  Maybe one type is enough to make it simple, but we’re open to discuss.  Not for all techniques studied for normal PUSCH can be applied to msg3, and some of the techniques like frequency hopping on different repetitions may be important here for Msg3 as well, but we can discuss later. |
| Samsung | For Q3-1, Q3-2, these two questions are related to the design details for the enhancement, which can be revealed and concluded more in next meeting. From our point of view, the PUSCH repetition type A and B can serve as starting point.  For Q3-3, the exact enhancements in normal PUSCH has not yet decided, it’s open to discuss and a little bit early for now. |
| Sharp | Q3-1: Indication can be in RAR UL grant, or RRC or others.  Q3-2: Either can be discussed.  Q3-3: Depends on further discussion. On the other hand, background of msg3 PUSCH and other PUSCH is different (I.e., legacy msg3 PUSCH doesn’t support repetition). Therefore, we think introduction of repetition for msg3 PUSCH may be prioritized. |
| CATT | 1. The indication can be explicit or implicit 2. Type A is sufficient 3. Agree with Ericsson and open to discuss |
| vivo | For Q3-1, since there is no reserved field in UL grant in RAR, we suggest to use some reserved bits in PDCCH scheduled with RA-RNTI. For legacy UEs transmit PRACH in the same RO, this field can be ignored.  For Q3-2, both Type-A and Type-B PUSCH repetition can be considered.  For Q3-3, depending on solutions, some of the solutions may depending UE capability, gNB may not aware of UE capability before RRC connection. |
| Intel | Q3-1: indication can be in RAR UL grant. In order to ensure backward compatibility, some fields may be repurposed to indicate the repetition level of Msg3 transmission.  Q3-2: We think repetition type A would be sufficient.  Q3-3: We are also open to discuss it after we have better understanding of the solutions for normal PUSCH coverage enhancement. |
| Nokia/NSB | We are not sure we understand why we should discuss Q3-1 and Q3-2 at this stage of the study. Concerning Q3-3, agree with vivo.  Again, we are not sure it is appropriate to refer to “msg3” when considering PUSCH scheduled by UL grant. Further clarifications in this regard is welcome. |
| OPPO | For Q3-1, we are open to discuss the different indication design, explicit or implicit, RAR or DCI based.  For Q3-2, Either can be discussed.  For Q3-3, enhancement on normal PUSCH can be considered first, and then identify which solution can be also used for Msg 3 scheduled by RAR UL grant. |
| Apple | Q3-1: : Indication can be in RAR UL grant, or RRC  Q3-2: at least type A is supported.  Q3-3: To us, this should be case by case, we are open to discuss this. |

**[L]Q4: What’s view on enhancements to Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by TC-RNTI, including**

* **Q4-1: How to enable the repetitions or how to indicate the number of repetitions, and any other indication?**
* **Q4-2: Do you think it needs to support both PUSCH repetition Type A and repetition Type B?**
* **Q4-3: Do you think the potential enhancements agreed in PUSCH agenda 8.8.2.1 should be also applied to Msg3 re-transmission scheduled by DCI format 0\_0 scrambled by TC-RNTI?**
* **Q4-4: Any other comments?**

Note1: Depending on the conclusion on Q2, we can further discuss above questions for PUSCH scheduled by DCI format 0\_0 scrambled by C-RNTI.

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| **Companies** | **Comments** |
| IITH, Reliance Jio, IITM, CEWIT, Tejas Networks | While PRACH can support large cell sizes, the Msg3 PUSCH waveform using CP-OFDM is severely limited. We must consider using DFT-s-OFDM waveform and pi/2 BPSK modulation for this transmission to significantly enhance its coverage. All enhancements related to pi/2 BPSK done for regular PUSCH must also be replicated for Msg3. |
| Ericsson | For retransmissions, maybe we do not need to indicate the repetition factors in DCI, instead we can indicate whether repetition is applied/terminated or not, initial repetition factors is already in RAR.  Same type of repetitions as initial transmission, one might be enough, e.g. Type A.  Not for all techniques, we can discuss later. |
| Samsung | Similar reply to above questions. Generally, we think it’s a little bit early to discuss this. |
| Sharp | Same comment as Q3. |
| CATT | For retransmission, it can follow the repetition number of initial transmission. The impact on fallback DCI should be definitely avoided.  For the other questions, same comments as Q3. |
| vivo | For Q4-1, We suggest to indicate the repetition factor in DCI 0-0 scrambled with TC-RNTI, in which there are still some bits reserved, e.g. NDI and HARQ proc number.  For Q4-2, both Type-A and Type-B PUSCH repetition can be considered.  For Q4-3, depending on solutions, some of the solutions may depending UE capability, gNB may not aware of UE capability before RRC connection. |
| Intel | Q4-1: Indication can be explicitly included in the DCI format 0\_0 scrambled with TC-RNTI. We are open to discuss whether it can be based on the repetition level of Msg3 initial transmission.  Q4-2: We think repetition type A would be sufficient.  Q4-3: We are open to discuss it after we have better understanding of the solutions for normal PUSCH coverage enhancement. |
| Nokia/NSB | Agree with Samsung |
| OPPO | Same comment as Q3. |
| Apple | Same comment as Q3 |

## PRACH enhancement

The necessity of PRACH enhancement is still pending now. It needs to find some methdologies to settle it. During the email discussion in the first week, there are two options mentioned, and summarized as follows.

* Option1: Whether PRACH enhancement is needed or not is only based on evaluation on PRACH. That is, if there is a gap between the baseline performance and the target performance for PRACH, enhancement to PRACH is needed. Otherwise, no enhancement is needed.
* Option2: Whether PRACH enhancement is needed or not is not only based on evaluation on PRACH channel but also the interplay between PRACH and Msg3 PUSCH. That is, even if PRACH does not incur coverage issues, PRACH enhancement can still be considered as a way to enhance Msg3 PUSCH if Msg3 PUSCH enhancement is required based on evaluation. For instance, if PRACH repetitions were to be performed using several different beam configurations, this may significantly help msg3 coverage thanks to a possible more efficient beam-forming either at the UE or gNB side.

Basically, the main difference between above two options is whether to additionally consider the interplay between PRACH and Msg3 PUSCH. So, companies are encouraged to provide your answers on the following question.

**[H] Q5: Do you agree PRACH enhancement, e.g. multiple PRACH transmissions, can be helpful and used as a way to improve Msg3 PUSCH performance?**

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| **Companies** | **Comments** |
| Ericsson | Based on our understanding, multiple PRACH transmission discussed here is only to allow UE to attempt random access with double resources at the same time or different time, but whether the 1st attempt and 2nd attempt may take the best SSB or better SSB beam is still ramdom.  Multiple PRACH attempts with power ramping are already supported especially for UEs in poor coverage, where UEs can randomly select the SSB beam for PRACH resource selection in each attempt. Note that there’s no requirement in spec. that Msg3 will use the UL beam corresponding SSB beam determined for PRACH resource selection, it’s up to UE to select the UL beam and smart UEs can actually select the best SSB beam already.  Multiple PRACH transmission introduces more collisions among UEs since multiple PRACH occasions are used for each attempt that may make the performance of PRACH worse especially in case with high load. Multiple PRACH transmission may trigger more spec. changes as we need to think whether gNB should know which preambles are from one single UE or it should be transparent to gNB while UE will prepare a single Msg3 after receiving multiple RARs, or gNB should prepare to receive multiple Msg3 PUSCH transmissions from single UE, the RA procedure change will trigger discussions in both RAN1 and RAN2. This may also extend RA latency compared to simply relying on Msg3 repetition and retransmission and frequency hopping for the Msg3 enhancement.  So for Msg3 enhancement, in our view, we may need to focus on repetition, frequency hopping, together with retransmission already supported. |
| Samsung | We think in general the PRACH enhancement can help the msg3 PUSCH performance in case to improve the beam-forming gain.  For multiple PRACH transmission, E/// may mis-understand that is for DL beam (e.g., SSB beam) refinement, which is not, it’s actually provide opportunity for UE to transmit with different UL tx beams in one attempt. With this opportunity, the UE can try with narrower UL tx beam in msg.1, and then if UE successfully gets the RAR, it can apply the narrower beam for msg.3 transmission. The details of the design can be discussed in next meeting. The issues raised by E/// are not problematic.  Besides, we don't need to specifically link the PRACH enhancements to msg.3 enhancements, e.g., we have one then we don't need the other. Both of them can be considered. |
| Sharp | We are not sure if we fully understand “interplay”. Why PRACH coverage enhancement contributes to the coverage enhancement for msg3 PUSCH when the PRACH has sufficient coverage? |
| CATT | During random access, UE can certainly select which preamble is used based on the results of cell search. In theory, UE can select the best SSB and, on top of the best SSB, select the best preamble. I don’t see why it will be helpful for msg 3 transmission if a UE repeat or transmit multiple preambles with different resources. Even UE transmits multiple preambles, there is no way for a UE to identify which UL beam is better as gNB is unable to indicate such kind of information.  More importantly, it is too early to answer this question especially it is not justified at all.  For msg3 enhancement, we share the same views as Eriscson, i.e. we should focus on repetition, FH, etc. |
| vivo | NO  First, the evaluation method that associated MSG3 reception with MSG1 repetition is not discussed in SI, considering the limited TU in this SI, we would like to discuss the evaluation assumption and methodology on PRACH and MSG3 inter-action before determine whether this beam training procedure is helpful. We prefer to study MSG3 repetition first.  Besides, for a contention based PRACH procedure, multiple UEs may share the same RO for PRACH transmission, and UE may start to transmit PRACH on any available ROs associated with the selected SSB. gNB may have wrong estimation of the signal quality if multiple UE transmit the same preamble in the same RO resource. Therefore, the beam training using a non-dedicated preamble is doubtful. |
| Intel | It is also not clear to us why we need to link PRACH enhancements to Msg3 enhancement. This can be separate study point. Our view is that if we can identify the performance gap for PRACH, we are open to discuss it for PRACH coverage enhancement. But we prefer to study Msg3 repetition first. |
| Nokia/NSB | Fully agree with Samsung. We share the same understanding. According to the current RACH procedure, UE uses a certain TX beam to transmit msg1 (and, likely, msg3). If unsuccessful, this transmission can be repeated with increased power until either the UE receives msg2 from gNB or the configured max power at UE is reached (procedure continues in the first case and fails in the second). In practice, there is not guarantee that UE will transmit msg1 (and, likely, msg3), using a suitable and effective TX beam but “just a TX beam”. This has non-negligible impact on the coverage of both msg1 and msg3, and the one of the msg3 in particular due to PUSCH coverage limitations. In this context, the possible reusing of (at least part of the) transmission parameters of msg1 transmission for msg3 transmission is what we refer to as interplay between PRACH and msg3 PUSCH, as written above by FL. In practice, current RACH procedure can be highly inefficient at FR2, where maximizing the efficiency of the UL transmission is paramount to ensure a good outcome of (not only, but rather fundamentally) the RACH procedure itself.  Several directions and designs could be investigated to address this issue. One possibility is indeed what Samsung hinted at, i.e., UE could make use of a narrower TX beam to transmit msg1 and msg3 and achieve significant MIL gains. After all, if achieving these gains were not possible, then there would be no point in discussing how to make the best use of multiple antenna NR technology for coverage enhancement purpose (and how to properly model such gains), as we are doing in this SI. Of course, how to enable the UE to identify a suitable narrower TX beam, to achieve these gains, will have to be studied and evaluated by RAN1 in the context of the SI. Exploring possible trade-offs between KPIs, e.g., coverage, latency, collisions, resource utilization would be part the study. This would be fully aligned with the SID.  All in all, we think it is rather fair to say that results presented so far on PUSCH coverage at FR2, are anything but flattering and reassuring. It is absolutely fine to study many of the enhancements we have been discussing so far, e.g., repetitions for msg3, frequency hopping, retransmissions and so on. However, this may not be enough to solve the problems all companies highlighted. More importantly, we cannot assess it before the study. Additionally, such enhancements would also be characterized by trade-offs between KPIs to explore, e.g., coverage, latency, collisions, resource utilization would be part the study. Hence, we must be very careful before discarding options which could indeed solve the coverage shortage of msg3. There is no way to know which direction/option is suitable to meet the target, prior to the study itself. We would like to invite every company participating to this discussion to carefully consider this possibility and keep an open mind at this stage of the SI. |
| Qualcomm | We think some PRACH enhancements, e.g. multiple PRACH transmissions, can be helpful for improving the performance of Msg3 PUSCH. For example, reception of multiple PRACH can be used also for beam refinement at gNB, which can be beneficial for later messages, including Msg3 PUSCH |
| OPPO | Share the similar views as Qualcomm |

## Beam related enhancement during initial/random access procedure.

Based on the contributions from companies and the discussion in the first week, there are mainly the following candidate beamforming techniques:

* Candidate 1: Refining SSB beam gains, e.g. increasing the number of SSB beams. This could apply to beam refinement for all channels in random access procedure.
* Candidate 2: Multiple PRACH transmissions. This could apply to beam refinement for Msg2/3/4 in random access procedure.
* Candidate 3: Multiple PDCCH repetitions. This could apply to beam refinement for Msg3/4 in random access procedure.
* Candidate 4: Reporting the best SSB/early CSI/the best PDCCH instance in Msg3 PUSCH. This could apply to beam refinement for Msg4 in random access procedure. Note that, it is claimed by the proponent that early CSI report can also improve the performance of Msg4 by more accurate link adaptation.

It was mentioned by companies that the evaluation methodologies of different beam refinement schemes should be discussed before the beam refinement is adopted in the initial/random access procedure. There are no evaluation results showing the performance gain of beam refinement. Though it should be clear there exits performance gain for beam refinement, it’s a fair that the proponents can provide some quantitative evaluation results for their interested schemes. This would facilitate the decision on whether such schemes could be further studied. Thus, FL suggestion is to further discuss the following proposal.

**[H] Proposal: *Study the performance and specification impacts on early CSI and/or beam refinement for physical channels during initial/random access procedure.***

* + ***Companies are encouraged to provide the evaluation results for interested schemes in RAN1#103-e meeting.***

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| **Companies** | **Comments** |
| Ericsson | Fine with the proposal.  But it’s not clear to us how candidate 2 and candidate 4 help on the beam refinement. |
| Samsung | We are generally fine with the proposal.  However, we want to make it clear that the early CSI and the beam refinement are NOT same type of solution, we should not tie them in the proposal or in future discussion. so it’s better to separate them:  ***Study the performance and specification impacts on following for physical channels during initial/random access procedure.***   * ***Beam refinement methods*** * ***Early CSI reporting***   + ***Companies are encouraged to provide the evaluation results for interested schemes in RAN1#103-e meeting.*** |
| Sharp | We are OK with the proposal. |
| CATT | For option 1, it will bring more overhead from system perspective. For option 2, we don’t see the necessity as comments above. For option 3, the PDCCH can be transmitted with the same beam corresponding to the selected SSB. For option 4, msg 4 uses the same beam as the selected SSB.  We don’t see the motivation of any above four candidates. But we are open to discuss as the proposal is general enough. |
| vivo | Do not agree with the proposal  Before we discuss the solutions, we would like to first identify which channels are the bottleneck channels. In our evaluation, the DL broadcast channels are not bottleneck, hence beam refinements to enhance DL broadcast coverage (including DL in RACH procedure) is not necessary.  Besides, for beam refinement in initial/random access, as raised in our answer to Q5, beam refinement does not necessarily bring about better Rx beam at gNB, due to contention based property. Therefore, we would prefer to align the evaluation assumptions and methodology for each candidate in this meeting. |
| Intel | We share similar view as Vivo that we are not sure whether we can jump to conclusion without understanding whether some channels are performance bottlenecks. We suggest to wait until we have better understanding of the performance bottlenecks.  But we are open to discuss beam refinement in general. |
| Nokia/NSB | Agree with Samsung. We see this item as strongly related to the previous one. They target the same goal, i.e., studying and proposing methods to leverage the interplay and mutual effect of different aspects of the initial/random access procedure on the coverage of problematic physical channels (e.g., PUSCH) or signals/messages (e.g., msg3). We should also note that beam refinement can mean several things, for instance we can steer in refined directions or make the beam narrower, etc.  Having said this, it may be indeed clearer to keep the two items “beam refinement methods” and “early CSI reporting” separate, given the presence of candidate solutions related to SSB beams, PDCCH and so on. Once again, we think it is important to keep an open mind at this stage, given the importance of the problem at hand. |
| Qualcomm | Support the proposal |
| OPPO | Fine with the proposal |

## CSI enhancements

It is concluded in Rel-15/Rel-16 that, A-CSI is not repeated on PUSCH with or without UL-SCH. If PUSCH slot aggregation is enabled, A-CSI is multiplexed only in the PUSCH in the first slot CSI report triggered by DCI on PUSCH repetition Type B without UL-SCH is carried on the first nominal repetition with the other nominal repetitions discarded, and CSI report triggered by DCI on PUSCH repetition Type B with UL-SCH is carried on the first actual repetition. The corresponding conclusion/spec are attached in the appendix.

Similarly, PUSCH scheduled by DCI scrambled by SP-CSI-RNTI doesn’t support repetition, i,e, SP-CSI is not repeated on PUSCH. In addition, SP-CSI cannot be multiplexed with uplink data as clarified by the CR in the appendix.

In [22][24], it is observed that CSI on PUSCH is one of the coverage bottlenecks, and 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.

In the first round of email discussion in PUSCH agenda, CSI repetition on PUSCH is supported by majority companies, while 1 company has concerns and 1 company raises some clarification. The concern is that it is not helpful for NR coverage enhancement. But, as the simulation provided in [24], around 4 dB gain can be achieved with up to 8 repetitions of CSI (6+5 bits) on PUSCH for mid-band. The clarification is whether it is for CSI only or not. FL’s understanding is it is for both PUSCH with or without UL-SCH. Because, CSI repetition is not supported in both cases.

With above clarification, I’d like to check companies’ view on the following proposal:

***Proposal: Study A/SP-CSI repetition on PUSCH.***

* ***FFS the aspects to be enhanced, e.g., signaling indication, the applicable repetition type etc.***
* ***FFS whether the potential enhancements agreed in PUSCH agenda 8.8.2.1 should be also applied to CSI repetition on PUSCH.***
* ***Note, it is applied to PUSCH with and without UL-SCH for A-CSI repetition .***

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| **Companies** | **Comments** |
| Samsung | We don’t support this proposal.  We are not sure what the target channel really is, it’s UCI on PUSCH or purely a PUCCH channel. And the enhancement of CSI itself is to benefit neither PUSCH nor PUCCH. We would like the proponent to first explicitly and clearly clarify which channel is the actual beneficial from this enhancements. |
| Ericsson | A-CSI is a bottleneck that we identified during the performance evaluation, the reason is A-CSI can only be transmitted on PUSCH and can not be repeated. A-CSI is not supported in PUCCH with the format that can be repeated.  We need to study the how much gain is needed to enhance A-CSI in this agenda item. Either on PUSCH or PUCCH or both, and we’re open to discuss further.  The A-CSI is an important information to be used to determine the best downlink beam and proper scheduling information for the downlink transmissions so as to increase the capacity or total throughput of a cell. So, the enhancement of the A-CSI report performance is essential to improve the coverage and capacity of NR. |
| Sharp | PUSCH repetition for A-CSI may have non-negligible specification impacts. We suggest to rephrase “Study benefits and specification impacts on A/SP-CSI repetition on PUSCH”. |
| CATT | We are negative to this proposal. The question is whether we have sufficient tools to guarantee the coverage. I think the fundamental question is that whether the CSI can be transmitted to gNB successfully. If A-CSI on PUSCH is problematic, it can be transmitted in terms of P-CSI on PUCCH, which will be certainly enhanced in PUCCH enhancement agenda. We don’t see the necessity to enhance A-CSI on PUSCH.  But as we compromised in PUSCH, we can accept it for studying. Sharp’s revision is a good way to go. |
| vivo | We do not support this proposal, similar views with Samsung |
| Samsung | According to E/// comments,  “The A-CSI is an important information to be used to determine the best downlink beam and proper scheduling information for the downlink transmissions so as to increase the capacity or total throughput of a cell.”  Then to our understanding, the enhancement of CSI is to actually enhance DL channels. Which DL channel does the proponent find any problem due to unreliable CSI? It’s not clear from proponent’s contributions, in which we mostly find the DL channels are not ones with coverage issues. |
| Ericsson | **To address the concerns form Samsung on how CSI will affect the PDSCH:**  If CSI is not reliable, the PDSCH performance/PDCCH performance will of course be quite worse, note that we do not find performance issue for downlink is because we are assuming CSI is reliable with expected beamforming/antenna gain in our performance evaluation. Without correct CSI, the performance will be quite worse, especially in FR2 when more narrow beams are used.  We would like hear Vivo to clarify on the reason that we do not study A-CSI bottleneck in coverage enhancement because URLLC is studying this:  Will URLLC use same mythology and simulations assumptions as we discussed in agenda 8.8.1 to resolve the coverage issue of A-CSI signal? Do you think they will focus on the PUCCH format/PUSCH assumptions that we’re studying in this topic to check the performance difference between legacy A-CSI and repeated A-CSI(either on PUSCH or PUCCH) to decide whether the target is met? |
| Intel | We are fine to further study A-CSI repetition on PUSCH given that the potential coverage issue for A-CSI. But we are not sure whether SP-CSI enhancement on PUSCH is needed given that SP-CSI can be carried by PUCCH with repetition. In our view, there are already existing tools to enhance the coverage for SP-CSI. We are also fine with the updated proposal from Sharp, but removing SP-CSI.  “Study benefits and specification impacts on A~~/SP~~-CSI repetition on PUSCH”. |
| Nokia/NSB | We agree on the importance of reliable CSI information at gNB to ensure that results from simulations for the DL channels can be relied upon. On the other hand, the following considerations can be made:   * Concerning UL: Results in [22] seem to show that MIL of CSI over PUSCH is 15 dB higher than MIL of data over PUSCH. If this indeed the case, we are not sure we understand why the issue is about the CSI feedback and not about data. In other words, it is not clear (for now) how we can claim that coverage of CSI over PUSCH is a problem. * Concerning DL: Actual DL performance degradation due to poorer CSI at gNB may only be assessed through SLS, which is not the baseline tool for this SI (albeit allowed). On the other hand, we are discussing an antenna array gain model in 8.8.1.1 AI which could be used to account for less reliable CSI (among other things). Maybe this could be used to assess actual DL performance degradation in terms of MIL, given a certain assumed CSI unreliability? Would this help assessing if an actual problem for DL, due to unreliable CSI, can be acknowledged by more companies?   Considering the above, we are open to consider the possibility that a problem may exist, but we think there is no conclusive and, more importantly, widely accepted evidence that it does.  Maybe the following could be a starting point to consider for a proposal which could better capture the current situation?  ***Proposal: Assess whether A/SP-CSI on PUSCH contributes to create coverage bottlenecks in either DL and UL, and study benefits of potential enhancements, e.g., repetitions, if coverage bottlenecks due to A/SP-CSI are identified.*** |
| Qualcomm | Support the proposal |
| vivo | URLLC is WI in first place then it is natural that it is considered there rather than in SI here.  Furthermore, the purpose of this SI is to identify the bottleneck channels and from the evaluation results so far we haven’t seen PDSCH is the bottleneck. Of course if we put the target performance very high then every single channel will be bottleneck! For the cell edge UE, it is mainly rank 1 PDSCH and wideband CSI, and we don’t expect type II CSI (overhead is too large for cell edge UE to feedback). There are many parameters gNB can tweak to control the CSI payload for the cell edge UE. |
| Ericsson | @Vivo, we can not understand the argument that we should not studying CSI bottleneck in coverage enhancement topic is because URLLC is a work item and coverage enhancement is a study item. As we stated earlier URLLC and CE have different methodologies, performance bottlenecks identified. Note that I assume that your answer to our questions in previous comment in this table is “NO”.  One more question: how did you do beam selection for each PDSCH transmission in your simulation? Is your conclusion that PDSCH has no bottleneck still holds even when the beam selected is wrong in both FR1 and FR2?  Furthermore, besides beam selection, correct CSI is also essential to provide accurate information of link quality so that gNB can schedule the resources efficiently so as to improve the spectrum efficiency given that we also have throughput requirement on PDSCH.  We’re open to discuss any solutions that may help to solve the bottleneck of A-CSI, to move forward, the revision proposed from companies below is also fine to us:  **“Study benefits and specification impacts on A~~/SP~~-CSI repetition on PUSCH”.** |
| vivo | @Ericsson, thanks for response above. Now, the question is beam selection or CSI accuracy. I believe it is more of MIMO discussion. We need be clear here, whether we are discussing about the accuracy of beam selection/reporting/CSI in this SI. The question is how many bits of UCI payload are you considering? There is range of UCI payload variations depending on system configurations. What is system configuration/UCI payload in your evaluation of “CSI bottleneck”? To me if we just say A-CSI repetition without knowing the details is kind of blank cheque. If you considering type II CSI, of course there is coverage issue which has been identified during Rel-15 thus overhead reduction is further specified in Rel-16. |

In Rel-15/Rel-16, A-CSI on PUCCH is not supported. In [24], A-CSI on PUCCH is proposed since it is observed that the estimated maximum isotropic loss of CSI on PUSCH is worse than CSI on PUCCH. It is also proposed to support PUCCH repetition for A-CSI to improve the coverage performance.

Before discussing a specific proposal for A-CSI on PUCCH, I’d like to first check companies’ view on the following question.

**Q-6: If A-CSI repetition on PUSCH is supported, do you think it is still needed to support A-CSI repetition on PUCCH for coverage limited UE?**

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| **Companies** | **Comments** |
| Ericsson | It’s up to the performance evaluation to see whether A-CSI on PUSCH is still a bottleneck even repetition is allowed.  Since this is a first meeting, we can simply agree on which options might be worth studying so that to resolve the A-CSI performance issue. We’re open to discuss any solutions that can help. |
| Sharp | If coverage extension required by this SI is achieved by A-CSI repetition on PUSCH, additional enhancement for A-CSI is not necessary. |
| vivo | Agree with Sharp’s views |
| Ericsson | If A-CSI on PUCCH is already supported later in URLLC, we do not have to rely on the A-CSI on PUCCH, but we need to check whether A-CSI on PUCCH can make the A-CSI not a bottleneck which can be studied in the evaluation stage.  But the question here is “if A-CSI repetition on PUSCH is not supported, xxx”, not on PUCCH. Not clear what Sharp and Vivo mean, are u assuming the question is “if A-CSI on PUCCH is supported”? If A-CSI repetition on PUSCH is supported, we can simply simulate the A-CSI repetition and calculate the link budget then determine whether if A-CSI is still a bottleneck or not before determining whether other enhancement solutions is needed. We do not want to support both A-CSI repetition on PUSCH and A-CSI on PUCCH at the same time either if we can simply use one solution to solve the issue.  Whether A-CSI needs to be enhanced depends on the whether the bottleneck is identified, which is true based on our link budget evaluation.  **Regarding the argument that we can rely on SP-CSI and P-CSI instead**:  We cannot understand the argument here, the benefit of A-CSI should be clear when NR standard introduces this A-CSI on top of the P-CSI and SP-CSI. And we do not think we can think A-CSI and SP-CSI equally. Just try to list some differences here:  A-CSI compared to SP-CSI and P-CSI, can be triggered dynamically and can be based on the measurement on A-CSI-RS, P-CSI-RS and SP-CSI-RS, can trigger up to 63 different aperiodic reports via DCI, which means more instant and reliable CSI can be reported on time.  P-CSI report is mainly only on the PUCCH physical channel, for which the resource configuration also includes information about a periodically available PUCCH resource to be used for the reporting and cannot use A-CSI-RS.  SP-CSI report only happens on periodically occurring reporting instances in the same way as for P-CSI reporting. And actual reporting activation and deactivation requires MAC signaling (MAC CE).  SP-CSI can be reported on a periodically assigned PUCCH resource or can be done on a semi-persistently allocated PUSCH, when it’s on PUSCH, it is typically mainly used for larger reporting payloads. |
| Nokia/NSB | As we said for the previous point, we are not sure we can claim that A-CSI over PUSCH is a bottleneck (for UL coverage? DL coverage?), even after carefully checking results in [22]. We are open to agree of further investigating if it is the case, as we said above. Assuming it is, we think that the most natural action would be study enhancements for A-CSI over PUSCH, e.g., repetitions, and not considering PUCCH as an option. For completeness, and assuming such enhancements are deemed necessary after the study, we copy-paste here what we previously wrote during the email discussion:   * As we know, PUSCH repetitions and PUCCH repetitions operate according to different logics. In this context, if the same number of repetitions is configured, the time to transmit all the PUSCH repetitions is generally lower than the PUCCH counterpart. In a way, this can have a two-fold benefit:   + The "point" of the A-CSI report, which gNB generally triggers upon need, i.e., a lower latency to receive it is welcome, is better preserved;   + A larger number of PUSCH repetitions could be scheduled over the same time span. * PUCCH repetitions can consume a very large amount of UL resources in case of DL-heavy resource/slot allocations. This can severely impact achievable throughput over PUSCH (which is arguably the bottleneck in NR). The same does not necessarily apply to PUSCH. * PUSCH already supports repetitions and yet A-CSI reports over PUSCH cannot be repeated (as well as msg3, as we know). As far as we are concerned, even if assumed to add support to A-CSI report over PUCCH would still not imply automatically that such reports can be repeated. In other words, the appropriateness and feasibility of considering PUCCH repetitions in case of (hypothetical) A-CSI report over PUCCH would still need to be discussed prior to any study. Partially related to this, it may be also worth observing that receiving/decoding a PUCCH repetition is algorithmically rather different from receiving a PUSCH repetition. * PUSCH offers a large flexibility in terms of link adaptation. Actual “best” performance of PUSCH and PUCCH without repetitions, for UCI payload of 10-20 bits, may not be so different (optimal MCS/PRB selection can yield an MCL increase of several dBs over a static approach to MCS/PRB selection, as we showed in our contributions to #101-e and #102-e). * It would need to be properly discussed/assessed, and for this reason we only list it as the last item, but specification effort for enabling A-CSI repetitions over PUSCH may also be smaller.   Overall, we have serious doubts about the appropriateness of solving such (supposed, for now) coverage problems of/due to A-CSI reports by enabling such reports to be performed (and possibly repeated) over PUCCH. |

## Update of TR

**[L] Proposal: Capture the following updated structure in TR 38.830.**

**6.3 Coverage enhancements for channels other than PUSCH and PUCCH**

**6.3.1 Enhancements for PRACH**

**6.3.2 Enhancements for Msg3 PUSCH**

**6.3.3 Enhancements for PDCCH**

**6.3.4 Enhancements for PDSCH**

**6.3.5 Beam refinement for physical channels during initial/random access procedure**

**6.3.6 Others**

**Note: The title of 6.3.2 may be further updated based on further discussion on MsgA/CFRA PUSCH.**

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| **Companies** | **Comments** |
| Ericsson | Given the discussions so far in this email thread, it’s clear that Msg3 PUSCH and beam refinement for early downlink channels may need to be enhanced.  Based on the discussions in PUSCH/PUCCH enhancement email threads, A-CSI enhancement can be listed here as well assuming we will discuss it in this thread instead for A-CSI repetition on PUSCH and A-CSI on PUCCH.  For other channels we can discuss in “other” sub-bullet, we’re also fine to use specific sub-bullet for some other specific channel when it is identified as bottleneck in future.  According to above, we propose:  **6.3 Coverage enhancements for channels other than PUSCH and PUCCH**  **~~6.3.1 Enhancements for PRACH~~**  **6.3.1~~2~~ Enhancements for Msg3 PUSCH**  **~~6.3.3 Enhancements for PDCCH~~**  **~~6.3.4 Enhancements for PDSCH~~**  **6.3.2~~5~~ Beam refinement for physical channels during initial/random access procedure**  **6.3.3 A-CSI enhancement**  **6.3.4~~6~~ Others** |
| Samsung | We are fine to FL proposal, with the understanding that the final existence of these sections will be based on final outcome of the SI.  One suggestion to E///, we hope E/// could be a little bit open-minded to not just focus what you prefer to study. As RAN1 agreed PRACH/msg.3/PDCCH/PDSCH are still under discussion. The corresponding sections should be kept, while the one for CSI is un-decided. We don’t agree to include it. |
| CATT | It is really too early to discuss which can be included in TR at this stage. Most of the candidate channels are not justified or achieve a common understanding. We can only agree with including ‘enhancement for Msg3 PUSCH’ in the TR considering there are no objections or concerns on it.  It’s better to decide which can be included in TR in the next meeting. |
| v**ivo** | Based on previous agreements, for PDCCH, PDSCH and beam refinements, we should first study whether the enhancements are needed. If there is consensus on necessity of coverage enhancements for these channels, it can be discussed later. Therefore, we would prefer not to include PDCCH, PDSCH and beam refinements at the moment. If these channels are identified as bottleneck later, the TR can be updated accordingly in future.  **6.3 Coverage enhancements for channels other than PUSCH and PUCCH**  **6.3.1 Enhancements for PRACH**  **6.3.2 Enhancements for Msg3 PUSCH**  **~~6.3.3 Enhancements for PDCCH~~**  **~~6.3.4 Enhancements for PDSCH~~**  **~~6.3.5 Beam refinement for physical channels during initial/random access procedure~~**  **6.3.3 Others**  For A-CSI, we would prefer study A-CSI on PUCCH in URLLC WI… Since, the Enhancement of CSI is to enhance the coverage of PDSCH, which is the best physical channel in our evaluation. Therefore, it should be deprioritized in coverage enhancement SI. |
| Ericsson | For some concerns from Rakesh and Qi, please find our clarification in section 2.4.  Regarding Qi’s comments in this table:  We’re open to list all details in this bullet, but the one listed here should be identified as bottleneck which should be interested by all companies. We’re only interested in real bottlenecks that we find in the performance evaluation. We’re also open to not list anything here and wait for the performance evaluation results in next meeting and still use the main bullet.  So far, we only see A-CSI on PUSCH, possibly Msg3 PUSCH (?), are identified as bottleneck, and early CSI/beam refinement may be possible to improve downlink broadcasting channels. Note that we do not think your argument is valid regarding that A-CSI do not need to be enhanced because PDSCH is not identified as bottleneck when the assumption is A-CSI is accurate (best beam is used). Please find our clarification in section 2.4. |
| Intel | We share similar view as other companies, it is too early to conclude the structure, which is highly dependent on the outcome of evaluation in AI 8.8.1. It may be good to wait before we conclude whether some channels need further enhancement first. |
| Nokia/NSB | Agree with Samsung. We propose the following modification to the proposal:  **Proposal: Capture the following ~~updated~~ tentative structure in TR 38.830.**  **6.3 Coverage enhancements for channels other than PUSCH and PUCCH**  **6.3.1 Enhancements for PRACH**  **6.3.2 Enhancements for Msg3 PUSCH**  **6.3.3 Enhancements for PDCCH**  **6.3.4 Enhancements for PDSCH**  **6.3.5 Beam refinement for physical channels during initial/random access procedure**  **6.3.6 Others**  **The above structure will have to be confirmed, or updated, after RAN1 #103-e, depending on the final outcome of the SI.** |
| Qualcomm | Support the proposal |
| OPPO | We are fine to the proposal |
| Apple | Until now, it seems only Msg3 PUSCH is agreeable for everyone to enhance further. So maybe we can put bracket for the items except the section 6.3.2, the bracket can be removed if it is identified as the coverage bottleneck. |

## Others

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

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| **Companies** | **Comments** |
| Ericsson | Given the discussions so far in PUCCH agenda, it looks companies want to put A-CSI on PUCCH in this agenda instead and we’re also find to put both A-CSI repetition on PUSCH and A-CSI on PUCCH to focus on the A-CSI bottleneck itself. |
|  |  |

# Discussion (1st week)

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.

|  |  |
| --- | --- |
| **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**

|  |  |
| --- | --- |
| **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.

|  |
| --- |
| - 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.

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |

## Updated proposal (1st 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.***

|  |  |
| --- | --- |
| **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 |
|  | FL’s view:  It’s fair to not list the details for MsgA for now since there are concerns, so I suggest to accept the change from Intel. We can certainly discuss further about the detailed enhancements for Msg A once we agreed to enhance.  Fine to add DMRS related enhancement. I intended not to include because it is not also discussing in PUSCH enhancement AI, and we can borrow the enhancement after there is progress there. But, given that there is possibility that the enhancement could be potentially different, it’s ok to list here for now. |

***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***

|  |  |
| --- | --- |
| **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. |
|  | FL view: As for the adding condition, similar to comments on PDCCH, I would suggest to change to ‘if PRACH enhancement is needed based on evaluation’. Given such condition is added and the only PRACH enhancement raised by companies so far is multiple PRACH transmissions, I would like to check whether the following format is acceptable.    ***Proposal 2: If PRACH enhancement is needed based on evaluation, study enhancements to 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~~*** |

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

|  |  |
| --- | --- |
| **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.**

|  |  |
| --- | --- |
| **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 |
|  | FL’s view: Thanks for the comments. It is also not accurate to categorize SSB related beam refinement to random access procedure. But we all agree the enhancement should be applied for the channels in random access. So, I would like to check whether the following change on top of the original proposal 3 is acceptable.  ***Study whether/how to enable potential techniques for early CSI and/or beam refinement for physical channels during random access procedure.*** |

***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.***

|  |  |
| --- | --- |
| **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.***

|  |  |
| --- | --- |
| **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. |
|  | FL’s view: As I commented above, 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.  So, I still suggest to use 'if PDCCH enhancement is needed based on evaluation' to address concerns form companies think PDCCH enhancement is not needed. Regarding PDCCH repetition, since namely all proponents support PDCCH repetition, I think it’s ok to explicitly list there. But I made the following changes to make it softer like other proposals.  In addition, I think it’s sufficient to say broadcast PDCCH. PDCCH in RACH procedure is also included based on the explanation of the subbullet.  ***Further updated Proposal 4: If PDCCH enhancement is needed based on evaluation, 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 unicast PDCCH*** * ***Study the aspects to be enhanced, e.g., PDCCH repetition.*** * ***~~FFS other enhancements.~~*** |

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

|  |  |
| --- | --- |
| **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. |

## Updated proposal (2nd round)

***Proposal 1-1:******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.***

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

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Samsung | Support. |
| Ericsson | Support FL’s updated proposal. |
| Intel | Support |
| InterDigital | We support the proposal from the moderator |
| Nokia/NSb | Support |
| vivo | Support |
| QC | Support |

***Further updated Proposal 2: If PRACH enhancement is needed based on evaluation, study enhancements to multiple PRACH transmissions in NR coverage enhancement SI.***

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Samsung | Support.  The “multiple” is needed as to clearly reflect what companies have proposed in the contribution so far, including repetition (with same preamble or different preambles). |
| Ericsson | “multiple” is not needed which is one of the options to enhance PRACH transmissions, we can compromise to take multiple PRACH transmission as an example, i.e. the proposed update:  ***Further updated Proposal 2: Proposal 2: If PRACH enhancement is needed based on evaluation, study enhancements to ~~multiple~~ PRACH transmissions in NR coverage enhancement SI, e.g. multiple PRACH transmissions.*** |
| Intel | We are fine with Ericsson’s update. |
|  | FL’s view:  Just like other proposals, we can make detailed enhancements to examples for now. Once it is agreed, we can further discuss the methodologies to determine whether PRACH enhancement is needed and also the detailed techniques. It should be ok to Ericsson’s modification. So, I made the following updates. |

***Further updated Proposal 2: If PRACH enhancement is needed based on evaluation, study enhancements to ~~multiple~~ PRACH transmissions in NR coverage enhancement SI, e.g. multiple PRACH transmissions.***

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| **Companies** | **Comments** |
| Huawei, HiSilicon | We don’t understand why to highlight “PRACH transmissions”, just study PRACH enhancement. So suggest a small change as  ***Further updated Proposal 2: If PRACH enhancement is needed based on evaluation, study it ~~enhancements to multiple PRACH transmissions~~ in NR coverage enhancement SI, e.g. multiple PRACH transmissions.*** |
| Nokia/NSB | Some companies expressed concerns on the appropriateness of the first formulation(s) of this proposal, given that we have not agreed yet that PRACH enhancements are needed (whereas, for instance, it is quite agreeable to every company already that study of enhancements of msg3 over PUSCH is a good way forward). However, it is unclear to us why this very specific, and generic, formulation is being chosen for PRACH enhancements and not for all the channels/procedures which are not unanimously considered as sources of possible coverage issues in the network, e.g., early CSI acquisition and PDCCH. This does not seem to capture companies views and concerns fairly (please see further proposed modifications in this sense to the related FL’s proposal in the corresponding tables).  Indeed, the current version of this proposal does not capture at all the following two aspects, which are very important in our view:   1. As we said multiple times so far, an evident operational interplay exists between the procedure for msg1 transmission and msg3 transmission, especially at FR2. The fact that msg1 transmission does not always incur coverage issues does not mean msg3 will not incur coverage issues, i.e., it is not the only aspect one should consider and simulate. It is quite straightforward in our view, for instance by looking at Figure 2(a) above, that if a msg1 repetition were to be performed using several different beam configurations (to be studied, of course), this may significantly help msg3 coverage thanks to a possible more efficient beam-forming either at the UE of gNB side (again to be studied). And we think we can all agree that more efficient beam-forming can only be helpful in this context, especially considering the challenges of guaranteeing good msg3 coverage. In this content, simulating a msg1 transmission without considering its impact on the subsequent msg3 transmission does not properly capture what happens in a real deployment. Hence, both transmissions should be considered in the evaluation when assessing the performance of PRACH to ensure the complete picture is observed. In other words, what evaluation means in this proposal is really unclear and partial. We thus suggest removing it. 2. In the discussion on 8.8.1.1 we are discussing the possibility of letting operators suggest performance targets for different channels/procedures in RAN1 #103-e. There seems to be a consensus that indeed such targets should exist in a form or another. This has a very evident implication: channels/procedures may be considered as in need of enhancement w.r.t. the performance target, regardless of the qualitative performance of a channel/procedure in simulation. If this rationale is accepted and shared by everyone, then this is a further motivation to remove to remove the reference to evaluation and/or revert the proposal to its previous formulation.   The following modification would address our concerns and arguably reflect more accurately companies’ concerns (including Nokia’s) on proposal 3 and 4:  ***Further updated Proposal 2: Study whether/how to enable enhancements to RACH procedure, e.g. multiple PRACH transmissions, in NR coverage enhancement SI.*** |
| vivo | We are fine with the proposal |
|  | *Further comments from HW copied by FL from email:*  Further updated Proposal 2: If PRACH enhancement is needed based on evaluation, study it ~~enhancements to multiplePRACH transmissions~~ in NR coverage enhancement SI, e.g. multiple PRACH transmissions.  *Further comments from Ericsson copied by FL from email:*  Regarding the proposal 2, we’re fine with the version further updated by Huawei:  **Further updated Proposal 2: If PRACH enhancement is needed based on evaluation, studyit ~~enhancements to multiplePRACH transmissions~~ in NR coverage enhancement SI, e.g. multiple PRACH transmissions.**  *Further comments from FL from email:*  For proposal 2, I think Marco made a point there. That is, interplay exists between the procedure for msg1 transmission and msg3 transmission, especially at FR2. The fact that msg1 transmission does not always incur coverage issues does not mean msg3 will not incur coverage issues. So current wording may preclude the possible interplay with Msg3 and the enhancement is only based on the evaluation on its own. To be more general, I would like to have another try on Proposal 2 by updating as follows. Hope it is acceptable for all.    **Further updated Proposal 2: If PRACH enhancement is needed ~~based on evaluation~~, study it in NR coverage enhancement SI, e.g. multiple PRACH transmissions.**  *Further discussion from email:*  **Nokia confirmed the support of above FL suggestion. CATT clarified and fine with above FL suggestion.** |

**Further updated Proposal 2: If PRACH enhancement is needed~~based on evaluation~~, study it in NR coverage enhancement SI, e.g. multiple PRACH transmissions.**

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

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Samsung | I think FL’s previous updated proposal is better.  **Study whether/how to enable potential techniques forbeam refinement during initial access procedure and/or early CSI during random access procedure.** |
| Ericsson | Support FL’s updated proposal. |
| Intel | Support. |
|  | *Further comments from Ericsson copied by FL from email:*  For P3, what we meant is to not limit the techniques discussed here only to enhance physical channels in initial access. Random access covers both initial random access and non-initial random access. Hope this clarifies. So below proposal is more general than the current one, which is preferred at this stage.  ***Further updated Proposal 3: Study whether/how to enable potential techniques for early CSI and/or beam refinement for physical channels during random access procedure.***  *Further comments from Samsung copied by FL from email:*  For P3, initial access procedure includes both DL sych and UL RACH, and random access includes both initial random access or non-initial random access case.  I assume E/// also don't want to limit the applicable scenario, so one suggestion could be    ***Further updated Proposal 3: Study whether/how to enable potential techniques for early CSI and/or beam refinement for physical channels during initial/random access procedure.***    Although it may have some duplication, it at least covers what has been proposed so far.  Hope it's acceptable. |
|  | FL’s view:  The intention from all companies are the same, i.e. to make it general at this stage. Above discussion is just to clarify the the understanding of initial access and random access procedure. It seems clear now that initial access procedure includes both DL synchronization and UL RACH during initial access phase, and random access includes both initial random access or non-initial random access case. There are some crossovers. So, the latest suggestion from Samsung should be ok for all, and recommended. |

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

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| **Companies** | **Comments** |
| Nokia/NSB | This proposal is drafted according to the same principles we highlighted for Proposal 2. In our view, this the direction we should follow for proposals 2, 3 and 4. |
| vivo | We are fine to study with med/low priority. |
| QC | Support |

***Further updated Proposal 4: 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.***

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Samsung | OK. |
| Ericsson | Support FL’s updated proposal. |
| Intel | Support |
| Huawei, HiSilicon | OK |
| Nokia/NSB | As we said earlier, we do not understand why:   * We need to be so specific in the description at this stage; * We follow inconsistent logics across different proposals, while it is clear companies have similar concerns for all of them (i.e., not everyone agrees on the appropriateness of a specific study)   We thus suggest being consistent and sufficiently general, following the spirit of other proposals and propose the following:  ***Further updated Proposal 4: study whether/how to enable PDCCH enhancements at least for broadcast PDCCH, in NR coverage enhancement SI, e.g., PDCCH repetition.***   * ***FFS unicast PDCCH*** |
| vivo | We are fine to study with med/low priority. |
|  | *Further comments from Ericsson copied by FL from email:*  Regarding proposal 4, we are not OK to remove the if condition since we do not see the bottleneck of PDCCH in the evaluation (similar to PRACH), but to move forward, we can compromise to:  ***Further updated Proposal 4:If PDCCH enhancement is needed based on evaluation, study whether/how to enable PDCCH enhancements at least for broadcast PDCCH, in NR coverage enhancement SI, e.g., PDCCH repetition.***   1. ***FFS unicast PDCCH***   *Further comments from FL from email:*  For Proposal 4, I would suggest to not change current proposal since there is no interplay there. I would to check again with Marco whether it is acceptable to you considering all the discussion here.  *Further comments from Nokia copied by FL from email:*  I confirm we can also support the current version of Proposal 4.  FL’s view: The current proposal 4 is acceptable for all. |

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

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| --- | --- |
| **Companies** | **Comments** |
| Samsung | OK. |
| Ericsson | Support FL’s proposal. |
| Intel | Support |
| Nokia/NSB | Ok |
| vivo | We are fine to study with low priority. |

# Agreements till now

**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.

# Reference

1. 3GPP RP-193240, “New SID on NR coverage enhancement”, China Telecom, RAN#86, Sitges, Spain, December 9th – 12th, 2019.
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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005732.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
24. R1-2006614 PUCCH coverage enhancement Ericsson

# Appendix

**Conclusion RAN1 #101-e:**

Conclusion in RAN1#96 with respect to A-CSI multiplexing in PUSCH with slot aggregation is interpreted as the following:

* When PUSCH slot aggregation is enabled, if A-CSI triggered by a DCI that schedules a PUSCH in a slot, the A-CSI is multiplexed only in the PUSCH in the first slot.
  + ~~A valid A-CSI is multiplexed only if the CSI computation corresponding timeline is met~~.
    - ~~The CSI computation timeline is referenced to the first slot of the slots with PUSCH repetition.~~
* No changes to the specifications are needed.

**TS 38.214 g20:**

\*\*\* Unchanged text is omitted \*\*\*

For PUSCH repetition Type A, when transmitting PUSCH scheduled by DCI format 0\_1 or 0\_2 in PDCCH with CRC scrambled with C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1, the number of repetitions *K* is determined as

- if *numberofrepetitions* is present in the resource allocation table, the number of repetitions K is equal to *numberofrepetitions*;

- elseif the UE is configured with *pusch-AggregationFactor*, the number of repetitions *K* is equal to *pusch-AggregationFactor*;

- otherwise *K=1*.

\*\*\* Unchanged text is omitted \*\*\*

For PUSCH repetition Type B, when a UE receives a DCI that schedules aperiodic CSI report(s) or activates semi-persistent CSI report(s) on PUSCH with no transport block by a *CSI request* field on a DCI, the number of nominal repetitions is always assumed to be 1, regardless of the value of *numberofrepetitions*. When the UE is scheduled to transmit a PUSCH repetition Type B with no transport block and with aperiodic or semi-persistent CSI report(s) by a *CSI request* field on a DCI, the first nominal repetition is expected to be the same as the first actual repetition. For PUSCH repetition Type B carrying semi-persistent CSI report(s) without a corresponding PDCCH after being activated on PUSCH by a *CSI request* field on a DCI, if the first nominal repetition is not the same as the first actual repetition, the first nominal repetition is omitted; otherwise, the first nominal repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213].

For PUSCH repetition Type B, when a UE is scheduled to transmit a transport block and aperiodic CSI report(s) on PUSCH by a *CSI request* field on a DCI, the CSI report(s) is multiplexed only on the first actual repetition. The UE does not expect that the first actual repetition has a single symbol duration.

\*\*\* Unchanged text is omitted \*\*\*

**Agreement**

The following text changes for TS38.214 are endorsed in [R1-2004855](file:///C:\Users\Docs\R1-2004855.zip) (TS38.214, Rel-15, CR#0100, Cat F) and [R1-2004856](file:///C:\Users\Docs\R1-2004856.zip) (TS38.214, Rel-16, CR#0101, Cat A).

|  |
| --- |
| 5.2.3       CSI reporting using PUSCH  A UE shall perform aperiodic CSI reporting using PUSCH on serving cell c upon successful decoding of a DCI format 0\_1 which triggers an aperiodic CSI trigger state.  An aperiodic CSI report carried on the PUSCH supports wideband, and sub-band frequency granularities. An aperiodic CSI report carried on the PUSCH supports Type I and Type II CSI.  A UE shall perform semi-persistent CSI reporting on the PUSCH upon successful decoding of a DCI format 0\_1 which activates a semi-persistent CSI trigger state. DCI format 0\_1 contains a CSI request field which indicates the semi-persistent CSI trigger state to activate or deactivate. Semi-persistent CSI reporting on the PUSCH supports Type I and Type II CSI with wideband, and sub-band frequency granularities. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.  CSI reporting on PUSCH can be multiplexed with uplink data on PUSCH except that semi-persistent CSI reporting on PUSCH activated by a DCI format is not expected to be multiplexed with uplink data on the PUSCH. CSI reporting on PUSCH can also be performed without any multiplexing with uplink data from the UE.  <unchanged text omitted>  6.1.4.2            Transport block size determination  For a PUSCH scheduled by RAR UL grant or  for a PUSCH scheduled by a DCI format 0\_0 with CRC scrambled by C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI, or  for a PUSCH scheduled by a DCI format 0\_1 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, ~~SP-CSI-RNTI,~~ or  for a PUSCH transmission with configured grant,  <unchanged text omitted> |