**3GPP TSG RAN#90e RP-20xxxx**

**e-Meeting, December 7th – 11th, 2020**

**Agenda item:**

**Source:** 3GPP TSG RAN1 Chairman

**Title:** Email Summary on Rel-17 Coverage Enhancements Work Item Scoping

**Document for:** Discussion/Decision

# Introduction

In this document, we will provide a summary on Rel-17 Coverage Enhancements Work Item scoping based on the following contributions:

* RP-202211 Power aspects for pi/2 BPSK in Rel-17 Indian Institute of Tech (H)
* RP-202267 Scope of Rel-17 WI on NR coverage enhancements Huawei, HiSilicon
* RP-202302 Coverage Enhancement study and WI scope for Rel-17 OPPO
* RP-202324 Views on the scope of Coverage Enhancement WI CMCC
* RP-202352 Views on Coverage Enhancement WI Intel Corporation
* RP-202355 On overlapping objectives across Rel-17 WIs Intel Corporation
* RP-202360 New WID on NR coverage enhancements China Telecom
* RP-202410 Views on WI for NR coverage enhancement Ericsson
* RP-202527 Views on coverage enhancement WID scope NTT DOCOMO, INC.
* RP-202530 On the scope of Rel-17 NR coverage enhancement Samsung
* RP-202559 Views on NR coverage enhancements WI Apple Inc.
* RP-202638 Views on WID scope for Rel-17 coverage enhancements vivo
* RP-202665 Views on WID scoping for Rel-17 NR coverage enhancement ZTE, Sanechips
* RP-202666 Views on Msg3 enhancement for Rel-17 NR coverage enhancement ZTE, Sanechips, Nokia, Nokia

Shanghai Bell, China Telecom, SoftBank, Thales, Sharp

* RP-202680 Views on Coverage Enhancement WI in Rel-17 Nokia, Nokia Shanghai Bell
* RP-202681 On the need for UL RACH enhancements in Rel-17 Nokia, Nokia Shanghai Bell, ZTE, Sanechips
* RP-202694 Way forward on NR Coverage Enhancements MediaTek Inc.
* RP-202711 Views on Rel-17 NR coverage enhancements CATT
* RP-202738 New WID: Power aspects for pi/2 BPSK in NR IITH
* RP-202745 Views on scope of NR Coverage enhancements WI Qualcomm Incorporated
* RP-202402 NR Coverage Enhancement and NTN THALES, Qualcomm, Firstnet, Fraunhofer HHI, Fraunhofer

IIS, Intelsat, Hughes Network Systems, ZTE, Panasonic, ESA, Oppo

# Proposals

The email discussion is organized as follows:

* General
  + To collect any general thoughts, e.g., interaction between RAN1 and other WGs, overall scoping vs. TU budget, etc.
* Justification
* Detailed Objectives
  + Potential PUSCH enhancements
    - To collected detailed thoughts on potential PUSCH enhancements
  + Potential PUCCH enhancements
    - To collected detailed thoughts on potential PUSCH enhancements
  + Potential enhancements for other channels
    - To collected detailed thoughts on other channels, particularly, msg3 and PRACH
  + Other aspects
    - To collected detailed thoughts on other aspects, e.g., those raised in RP-202211 and RP-202402, overlapped objectives across WIs, etc.

## General

Questions:

* Any general thoughts? e.g., interaction between RAN1 and other WGs, overall scoping vs. TU budget, etc.

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| **Company** | **Views** |
| Sierra Wireless | As we saw during the SI phase, having coverage enhancement work being done in two SI (CovEnh and RedCap) was very inefficient and should thus be avoided. The CovEnh WI should thus including as many Redcap Coverage requirements as will fit. If it helps, we can move TU’s from Redcap to CovEnh. |
| Samsung | We think the TU budget will be enough as almost all techniques are well understood and are not complex. |
| Intel | As described in our tdoc RP-202355, PUSCH-repetition-Type-B like PUCCH repetition and dynamic PUCCH repetition indication can be specified under either eURLLC/IIoT or CovEnh, potentially based on final scope size of CovEnh WI. Note that in this case it is important that the objective takes into account all technical requirements from eURLLC/IIOT, CovEnh, and Fe-MIMO. Overall, we suggest such overlapping issue to be discussed under another email thread (e.g. under [26]). |
| ZTE | Regarding the overlapped objectives with Redap WI, we think all coverage enhancement/recovery objectives should be included in CE WI with the following reasons.   * As discussed in CE SI, some regular PUSCH enhancements can be applied to Msg3 PUSCH but repetition has to be enabled for Msg3 first before these enhancements can be applied to Msg3. Therefore, it would be more reasonable to introduce PUSCH and Msg3 enhancements together in the CE WI. * The solutions studied in CE SI are generally common solutions and can be applied to both CE UEs and RedCap UEs. Including all potential coverage enhancement objectives in CE WI can avoid duplicated work among different WIs. |
| vivo | Overall scope should be reasonable, overlapping issues to be discussed in separate thread however discussion here should also consider potential outcome. We prefer coverage of UL channels are considered in this WI. |
| Apple | We prefer to prioritize the PUSCH and msg3 coverage enhancements. We are also supportive PUCCH enhancement, but overlapping with other WI needs to be clarified. |
| OPPO | We prefer the enhance the coverage of DL channel in RedCap, since it is RedCap-specific case. |
| CATT | Interaction between CE WI and RedCap WI should be considered together. At least coverage enhancements for PUSCH and Msg3 should be included in CE WI in our view. It also needs to be discussed and decided whether to enhance coverage for Msg2/4/PDCCH and whether it is included in CE WI or RedCap WI if agreed to be enhanced.  The overlapping between CE WI and IIoT WI is mainly about PUCCH enhancements. In our view, only the techniques which improves coverage should be included in CE WI. |
| Nokia, NSB | Priority should be given to the channels and enhancements where consensus has been reached during the SI, and those addressing the main coverage bottlenecks. We do not see it feasible to address all potential channels of interest in the given TU budget. Moreover, from the TR conclusions there is no particular reason to prioritize PUCCH over the other channels, in fact it should have lower priority compared to msg3 and PRACH. |

Proposals:

* TBD

## Justification

Rappoetuer’s draft for justification (as in RP-202360):

*Coverage is one of the key factors that an operator considers when commercializing cellular communication networks due to its direct impact on service quality as well as CAPEX and OPEX. Many countries are making available more spectrum in FR1, such as 3.5GHz, which is typically in higher frequencies than for LTE or 3G. Furthermore, Compared to LTE, NR is designed to operate at much higher frequencies such as 28GHz or 39GHz in FR2. Due to the higher frequencies, it is inevitable that the wireless channel will be subject to higher path-loss making it more challenging to maintain an adequate quality of service that is at least equal to that of legacy RATs. One key mobile application of particular importance is voice service for which a typical subscriber will always expect a ubiquitous coverage wherever she/he is located.*

*The Rel-17 study item 860036 “Study on NR coverage enhancements” evaluates the baseline performance for both FR1 and FR2. The following channels are identified as the potential bottleneck channels for FR1:*

* *1st priority*
  + *PUSCH for eMBB (for FDD and TDD with DDDSU, DDDSUDDSUU and DDDDDDDSUU)*
  + *PUSCH for VoIP (for FDD and TDD with DDDSU, DDDSUDDSUU)*
* *2nd priority*
  + *PRACH format B4*
  + *PUSCH of Msg.3*
  + *PUCCH format 1*
  + *PUCCH format 3 with 11bit*
  + *PUCCH format 3 with 22bit*
  + *Broadcast PDCCH*

*The following channels are identified as the potential bottleneck channels for Urban 28 GHz scenario:*

* + *PUSCH eMBB (DDDSU and DDSU)*
  + *PUSCH VoIP (DDDSU and DDSU)*
  + *PUCCH F3 11bits*
  + *PUCCH F3 22bits*
  + *PRACH B4*
  + *PUSCH of Msg3*

*The Rel-17 study item 860036 “Study on NR coverage enhancements” studies the enhancements for PUSCH, PUCCH and other channels/signals. The study item concludes that it is beneficial to support a set of enhancements for PUSCH, and further establishes detailed recommendations as given in Section 7 in TR 38.830.*

Questions:

* Any comments/suggestion on the justification of the work item?
  + Note that it is understood that discussion on justification for the work item depends on the discussion on the detailed objectives. This implies that a fully stable justification section may not be possible before the conclusion of the detailed objectives
  + However, it is necessary to have early discussion on the justification section so that some level of convergence can be achieved in parallel

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| **Company** | **Views** |
| Samsung | It is understood that current draft reflects the outcome of the study item. As the moderator noted, the need for a potential change in the justification text depends on the objectives. This can be discussed in the third/last phase of this email discussion once the objectives are being finalized. |
| Intel | We are in principle fine with the justification. This may need to be updated based on final conclusion of the detailed objectives. |
| ZTE | * As commented above, we suggest all coverage enhancement/recovery objectives should be included in CE WI. Therefore, for the justification part, we suggest to add a sentence like ‘Coverage enhancement techniques can be also applicable to RedCap UEs for the purpose of coverage recovery’. * In NTN networks, uplink channels, e.g, PUSCH, PUCCH and Msg3, could also the bottleneck channels, and the specified solutions in NR CE WI is not exclusive for only terrestrial networks. So, we suggest including NTN use cases in the justification. * Instead of explicitly referring to the conclusion/recommendations made within one section of TR 38.830, it seems sufficient to refer to the TR in general without more details. * As elaborated below, PUSCH, PUCCH, Msg3, PRACH could be the bottleneck channels, and corresponding enhancements are needed. We suggest including the necessity of enhancements on these channels in justification (depending on the discussion below of course). |
| vivo | Current draft of justification can be starting point to further polishing, final justification can be agreed according to detailed objectives. Objectives should be based on schemes studied and analysed thoroughly in CE study item,. New application scenario can be added in justification without expanding objectives. |
| Apple | One comment on potential bottleneck on FR1, to avoid the confusion, it could be better to add the condition why broadcast PDCCH is the potential bottleneck channel.  - Broadcast PDCCH (BS with 24dBm/MHz Tx power) |
| Nokia, NSB | The justification section reflects the outcome of the SI, and hence it is fine in principle. One minor editorial change that we could suggest is that the conclusions of the SI should be in past tense, as the SI has concluded already. For example “*The following channels are identified as the(…)”* should be *The following channels have been identified as the(…)”* |

Proposals:

* TBD

## Detailed Objectives

### Potential PUSCH Enhancements

Related RAN1 agreements/conclusion:

*Agreements: Capture the following observation into the TR.*

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

***Agreements:*** *Capture the following observation into the TR.*

*TB processing over multi-slot PUSCH is beneficial for PUSCH coverage enhancements. It is recommended to support TB processing over multi-slot PUSCH in Rel-17, including:*

* *TBS determined based on multiple slots and transmitted over multiple integer slots.*

***Agreements:*** *Capture the following observation into the TR.*

*Joint channel estimation is beneficial for PUSCH coverage enhancements. It is recommended to support Joint channel estimation or DM-RS bundling for PUSCH in Rel-17, including:*

* *Joint channel estimation over consecutive PUSCH transmissions*
* *Inter-slot frequency hopping with inter-slot bundling*

Rappoetuer’s recommendation (as in RP-202360):

* + Specify one or two options for enhancement on PUSCH repetition type A [RAN1]
    - Option 1: Increasing the maximum number of repetitions, e.g., up to 32.
    - Option 2: The number of repetitions counted on the basis of available UL slots.
  + Specify mechanism to support TB processing over multi-slot PUSCH [RAN1, RAN4]
    - TBS determined based on multiple slots and transmitted over multiple integer slots. [RAN1]
    - [Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]
  + Specify mechanism to enable joint channel estimation [RAN1, RAN4]
    - Mechanism to enable joint channel estimation over consecutive PUSCH transmissions, including cross-slot channel estimation over consecutive slots and joint channel estimation over multiple PUSCH transmission within one slot [RAN1]
    - Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]
    - Specify the requirements for power consistency and phase continuity [RAN4]

Questions:

* Do you agree with the recommended scope for potential PUSCH enhancements? Why/why not?
  + Please elaborate detailed thoughts

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| **Company** | **Views** |
| Sierra Wireless | In general, agree. Some specific comments:  We would like to make this change to this bullet:   * + - Option 1: Increasing the maximum number of repetitions~~, e.g.,~~ up to 32.   Increasing repeats beyond 32 would move into the LPWA (NB-IOT/LTE-M) type coverage category which should be strictly avoided. Also, >32 repeats would significantly decrease spectral efficiency and adds no coverage for eMBB case where data rate is 100kbps.  We would like to make these changes to this bullet:   * + - ~~[~~Sub-PRB transmission with multi-slot aggregation~~, e.g. 6 tones~~ [RAN1, RAN4]~~]~~   We do not think it is appropriate or needed for RAN PL to give guidance on the number of sub-carriers- WGs will make that decision.  Editorial: “mechanism” should be “mechanism(s)” throughout |
| Samsung | For PUSCH repetition type A, we support to specify Option 2.  For TB processing over multi-slot PUSCH, both solutions in the two sub-bullets provide gains by transmitting over multiple slots. Sub-PRB solution has been shown providing gains for the VoIP use case. We suggest to specify both.  The word “integer” is ambiguous. If the intention is to exclude a mini-slot, there is no need to add it because the description already clarifies that the processing is over multiple slots.   * Specify mechanism to support TB processing over multi-slot PUSCH [RAN1, RAN4]   + TBS determined based on multiple slots and transmitted over multiple ~~integer~~ slots. [RAN1]   + ~~[~~Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]~~]~~   For joint channel estimation, we are fine with the current description. |
| Intel | We are generally fine with the recommendated scope for potential PUSCH enhancement, which is mostly based on the outcome of NR CovEnh SI.  For sub-PRB transmission with multi-slot aggregation, we are open to discuss it but this may also depend on overall scope and time budget of NR CovEnh WI. |
| Panasonic | Not to support sub-PRB in order to manage TU. To take the other recommendations is in-line with the RAN1 recommendations. |
| ZTE | Regarding sub-PRB transmission over multi-slot, compared to legacy repetition scheme, no or very limited LLS performance gain is observed as captured in the TR 38.830. Some gain in terms of MPR reduction may exist due to new waveform design. In this context, it’s better not to categorize sub-PRB transmission with TB processing over multi-slot PUSCH. Considering the limited performance gain and relatively large spec impacts across RAN1 and RAN4, we prefer not include it in the WID.  We are fine with other items. |
| vivo | Although above items are recommended by RAN1, some of the techniques are not well analysed during SI, spec impact and complexity for “TB processing over multi-slot PUSCH” are not well studied, for example what impact SFI may have, how flexible slot is used, how UCI is multiplexed etc. On the other hand, performance is similar to “enhancement on PUSCH repetition type A” from the coverage gain point of view.  Regarding sub-PRB transmission with multi-slot aggregation, there was no consensus on potential gain, and spec impact is quite large, we do not support. |
| SoftBank | According to the result of RAN1 study, it was identified that PUSCH is the worst channel for many senarios. PUSCH (eMBB and VoIP) should be included in the scope of this WI. |
| China Telecom | We support to specify the three recommended enhancements.  In addition, we are supportive of sub-PRB transmission with multi-slot aggregation. We see it is beneficial for VoIP. Regarding the spec impacts, “sub-PRB transmission with multi-slot aggregation” shares the most spec impacts of “TB processing over multi-slot PUSCH”. Thus it can be one special case of “TB processing over multi-slot PUSCH”. |
| Apple | For sub-PRB transmission, according to the simulation results in the study, the link budget gain is observed only with 6 tones transmission, or even without gain. If it is agreed to support sub-PRB transmission, to limit the objective and align the study,   * [Sub-PRB transmission with multi-slot aggregation, ~~e.g.~~ i.e., 6 tones [RAN1, RAN4]]   One comment on joint channel estimation, the specifying requirements for power consistency and phase continuity is not clear, is the requirement to gNB or UE? To our understanding, the intention is clarify the conditions that the gain of joint channel estimation could be achieved, if the conditions are not fulfilled, then joint channel estimation is falling back to traditional channel estimation. In this sense, this buellet can be updated as,   * ~~Specify the requirements for~~ Specify the condtions to keep power consistency and phase continuity [RAN4] |
| OPPO | For the 2 “[]”, we need plenary conclusion whether to include or no.  The“[Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]”, suld not be sub-bullet of TBS over multiple-slot. It is not bound as sub-solution. |
| CATT | We are supportive of the proposed scope including sub-PRB transmission with multi-slot aggregation.  For joint channel estimation, we propose to remove the details to be aligned with the recommendation as capture in the TR.   * + Specify mechanism to enable joint channel estimation [RAN1, RAN4]     - Mechanism to enable joint channel estimation over consecutive PUSCH transmissions~~, including cross-slot channel estimation over consecutive slots and joint channel estimation over multiple PUSCH transmission within one slot~~ [RAN1]     - Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]     - Specify the requirements for power consistency and phase continuity [RAN4]   We agree with Samsung’s suggestion to remove “integer”. |
| NTT DOCOMO | Yes, the recommended three soltions would provide effective gain with reasonable work load. In addition, since approximately 8 dB (e.g. in 4 GHz Urban scenario) enhancement for PUSCH may be necessary based on the study for the baseline coverage performance, multiple coverage enhancement techniques would be necessary to achieve the target coverage performance for PUSCH. |
| InterDigital | We support the Rappoetuer’s recommendation to include all normative items agreed in RAN1, namely specifying “one or two options for enhancement on PUSCH repetition type A”, “mechanism to support TB processing over multi-slot PUSCH” and “mechanism to enable joint channel estimation.”  Regarding the subitem for TB processing over multiple slots, we don’t support sub-PRB transmission to save time for other high priority topics with the limited TU. |
| Nokia, NSB | The objectives above are fine with the exception of “[Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]”, which should not be included for the sake of keeping the scope of the WID reasonable. |

Proposals:

* TBD

### Potential PUCCH Enhancements

No consensus in recommendation was made by RAN1, although a variety of aspects were discussed for potential PUCCH enhancements.

Rappoetuer’s recommendation (as in RP-202360):

* Specification of PUCCH enhancements [RAN1, RAN4]
  + [Specify DMRS-less PUCCH with UCI payload up to 11 bits [RAN1, RAN4]]
  + [Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]]
  + [Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]]
  + [Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]]

Questions:

* Which one(s) of the above potential PUCCH enhancements would you recommend? Why/why not?
  + Please elaborate detailed thoughts

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| **Company** | **Views** |
| Sierra Wireless | No strong view but feel that only ONE mechanism should be chosen to fit in TU budget. |
| Samsung | PUCCH was identified as a bottleneck channel for coverage and we support to specify mechanisms to enhance PUCCH coverage. The SI concluded with no recommendations due to different views on which solutions to adopt, not on the need for PUCCH enhancements.  We support the second bullet on PUSCH-repetition-Type-B like PUCCH repetition for basically same reasons as for having PUSCH-repetition-Type-B. Repetitions for PUCCH are already possible and the introduction of optimizations similar to Rel-15/16 PUSCH repetitions (e.g., start symbol to be the same in each slot, single repetition per slot, etc.) improve resource utilization/latency/coverage with a limited impact to specifications and gNB/UE implementations. Also, Rel-17 MIMO agreed to have intra-slot PUCCH repetitions to different TRPs to improve coverage – it would not make sense to preclude single TRP.  We support the third bullet on dynamic indication of PUCCH repetition as it improves resource utilization/coverage. It is useful to adjust the number of repetitions to the number of PUCCH symbols and UCI payloads as a transmission power cannot increase over the repetitions. This can be done by indicating the number of repetitions for a PUCCH transmission by the DCI format triggering the PUCCH transmission.  We support the fourth sub-bullet as we also support it for PUSCH and expect the requirements to be practically same.  In summary,   * ~~[~~Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]~~]~~ * ~~[~~Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]~~]~~ * ~~[~~Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]~~]~~ |
| Intel | We do not support “Specify DMRS-less PUCCH with UCI payload up to 11 bits”. As illustrated in our tdoc RP-202804, performance difference existing PUCCH format 3 and DMRS-less PUCCH scheme is negligible, for various UCI payload size from 3 to 11 bits, and for different performance metrics including BLER and ACK performance. Further, the impact at gNB reciver is substantial if DMRS-less PUCCH scheme. In our view, the need to consider DMRS-less PUCCH scheme for PUCCH coverage enhancement is not justified and we do not support it.  PUSCH repetition type B like PUCCH repetition enhancement and dynamic indication of PUCCH repetition factor can be specified for PUCCH coverage enhancement. Whether this can be specified under eURLLC or CovEnh WI can be further decided based on overall scope and time budget. In our view, both schemes can help in improving the PUCCH coverage compared to existing PUCCH repetition mechanism. For instance, assuming special slot of 7 UL symbols and 14-symbol uplink slot, PUCCH repetition enhancement following PUSCH repetition type B can be employed to transmit 7-symbol long PUCCH with 3 repetitions, while existing PUCCH repetition scheme can only have 2 repetitions.  Similar to PUSCH coverage enhancement, DMRS bundling across PUCCH repetitions should be considered as an objective for PUCCH coverage enhancement, which includes joint channel estimation and inter-slot frequency hopping with inter-slot bundling. |
| Panasonic | "Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]" can be within URLLC.  "[Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]]" is quite similar to PUSCH and it should be within the scope.  On "[Specify DMRS-less PUCCH with UCI payload up to 11 bits [RAN1, RAN4]]", some more discussion of the frequency and timing error would be required to satisfy the existing functionalities.  On "[Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]]", not to take it because of the lack of TU. |
| ZTE | We support the 1st and 3rd items.  Regarding DMRS-less PUCCH, we are supportive since majority companies observe clear performance improvement during RAN1 discussion. We are also fine to consider to add some limitations to reduce the specification impacts, e.g, only for long PUCCH format. |
| vivo | For PUCCH enhancement, our recommendation is to support PUSCH-repetition-Type-B like PUCCH repetition, the overall mechanism can be similar to PUSCH-repetition-Type-B, in this sense overall work is limited. DMRS bundling is considered together with repetition. |
| SoftBank | We are OK to include this in the scope of this WI. However, we would emphaseize that Msg.3 PUSCH has higher priority than PUCCH from our perspective. This aspect should be taken into account when we need to give up something due to e.g. TU shortage. |
| China Telecom | We think PUCCH enhancement is necessary. Considering the work load, one or two solutions can be included in the WID. |
| Apple | If PUCCH is considered as the bottleneck channel, dynamic PUCCH repetiton factor indication is preferred. The standard impacts and workload are moderate considering the TU allocation. We are also open to discuss further DMRS-less PUCCH. For PUSCH repetition type B like PUCCH repetition, the use case for coverage enhancement is not clear enough, it could be benefitial from latency reduction perspective, thus this could be discussed at eURLLC WI. |
| OPPO | The PUCCH is observed as a channel close to PUSCH. Should be both enhanced.  We think the DMRS-less PUCCH, dynamic PUCCH repetition and DMRS bundling can be supported. The DMRS-less can bring coverage enhancement in single slot. The dynamic PUCCH repetition will improve resource efficiency. Bundling is natual results if phase continuity kept.  Type B repetition can be considered to revise if the “mini-slot” capability is not required. E.g the repetition can be slot based but reuse some TypeB mechanism. Or, we can further justify it in WI earlier stage. |
| CATT | In general, it is not feasible to include all the PUCCH enhancements techniques in the WI. In our view, no more than two techniques should be selected from the four candidates to make sure that the scope is managable. We would like to prioritize dynamic PUCCH repetition factor indication and DMRS bundling considering the moderate specification impact. We do not agree to include PUSCH-repetition-Type-B like PUCCH repetition considering that the performance gain in terms of coverage enhancements have not been justified, it is a payload size dependent solution, and the specification impact would be large. |
| NTT DOCOMO | We don’t have strong preference on any specific solution. However, approximately 1-2 dB enhancement may be necessary for format 1 and format 3 with 11 bits pay load size, and 5-6 dB enhancement may be necessary for format 3 with 22 bits pay load size based on the study for the FR1 baseline coverage performance. Therefore, multiple coverage enhancement techniques would be necessary to achieve the target performance for PUCCH. |
| InterDigital | In general, we are supportive to include PUCCH enhancement as it was identified as a bottleneck channel during study. For the enhancement schemes, we support DMRS-less PUCCH with UCI payload up to 11 bits for power efficient PUCCH transmission and DMRS bundling across PUCCH repetitions to enhancem channel estimation performance. Regarding DMRS-less PUCCH, we are also fine to limit the scope to long PUCCH only if it helps for TU management. |
| Nokia, NSB | Indeed no consensus has been achieved in RAN1 to support PUCCH enhancements. In fact, it has been shown that the need for PUCCH enhancements is lower than the need for enhancements to channels/signals involved in RACH procedure, both in FR1 and in FR2. Hence, there is no reason to assume that the WID must include PUCCH enhancements, and such enhancements can only be potentially considered with lower priority compared to the other channels (i.e. msg3 and PRACH).  It should be noted that PUCCH repetition is already under consideration in other WIs, and one needs to clarify what extra enhancements would need to be considered here on top of what is already addressed by IIOT/URLLC and Fe-MIMO (Multi-TRP).  In addition, DMRS-less PUCCH and PUSCH-repetition-Type-B like PUCCH repetition would require significant standardization effort, and if any of those techniques are to be considered, then there is a need to reduce the overall scope of the WID, including the PUSCH aspects that have been recommended by the TR. |

Proposals:

* TBD

### Potential Enhancements for Other Channels

No consensus in recommendation was made by RAN1, although a variety of aspects were discussed particularly for msg3 and PRACH enhancements.

#### Potential Msg3 Enhancements

Rappoetuer’s recommendation (as in RP-202360):

* [Specify mechanism to support PUSCH repetitions for Msg3 [RAN1]]

Questions:

* Would you recommend supporting PUSCH repetitions for Msg3? Why/why not?
  + Please elaborate detailed thoughts

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| **Company** | **Views** |
| Sierra Wireless | Recommend for inclusion in WI. Should not be large item and would be good for RedCAP UEs with 3dB antenna degradation. |
| Samsung | Msg3 PUSCH and PRACH were identified as bottleneck channels for coverage in some scenarios. Coverage enhancements are especially needed for FR2 as observed in the evaluation, and in real deployments as pointed out by various operators in SI discussions.  Msg3 PUSCH cannot benefit of the beam refinement mechnisms available in connected mode, and relying on retransmissions for Msg3 PUSCH is inefficient. We recommend to specify mechanism to support PUSCH repetitions for Msg3. |
| Intel | We support to specify coverage enhancement for Msg3 PUSCH.  As outcome of NR CovEnh SI, Msg3 PUSCH was identified as potential bottleneck channels at least for FR2. As captured in Table 5.2.2-1 in TR38.830, relative difference between Msg3 PUSCH and reference channel, i.e., PUCCH format 1 in Urban 28GHz with O2I is 3.4dB. In our view, Msg3 PUSCH needs to be enhanced in order to meet the target requirement. During NR CovEnh SI, Msg3 PUSCH with repetition was investigated extensively as solutions for coverage enhancement. So we support to specify mechanism to support PUSCH repetitions for Msg3. |
| Panasonic | Yes. Trying to have the common design with PUSCH enhancement as much as possible. |
| ZTE | We support Msg3 PUSCH repetitions in NR CE WI, with the following reasons.   * For some scenarios with VoIP traffic in FR1, the MIL gap between Msg3 and PUSCH for VoIP is very small e.g. 0.07 dB in Rural 4GHz scenario or 0.56 dB in Rural 700MHz scenario. Given regular PUSCH is expected to be enhanced in Rel-17, Msg3 would become the worst bottleneck channel for VoIP traffic considering the impact of standard deviation of MIL value and very easily compensated marginal gap by applying the supported enhancements for regular PUSCH. In other words, Rel-17 coverage is limited by Msg3 coverage in some scenarios if Msg3 is not enhanced. * In urban scenario in FR2, most of UL channels have quite large coverage shortage especially for O2I case. It implies that enhancement on Msg3 is very desirable to improve the coverage in FR2 overall. * We’d also like to emphasize that Msg3 enhancement has gained a vast majority companies’ support during RAN1 discussion, and operators have proposed several relevant scenarios for Msg3 enhancement, e.g., heterogeneous network, outdoor gNB serves deep indoor UE, isolated cell in the countryside, and increasing coverage or data rate of Msg3. * In addition, Msg3 enhancement is needed for coverage recovery for Redcap UEs and could also be beneficial for NTN use cases. |
| vivo | It is recommended to support Msg3 repetition, which is also recognized as bottleneck in Redcap SI. |
| SoftBank | According to the analysis in RAN1, enhancement of Msg3 looks useful for coverage enhancements. We would recommend it in the scope of CovEnh WI. |
| China Telecom | Yes. It has been identified that Msg3 is one potential bottleneck channel. Furthermore, from our perspective, we find that there exist some coverage issues for Msg3 in some scenarios, such as rural 4GHz, out door gNB serves deep indoor UE, etc. Thus, we think coverage enhancement for Msg3 is necessary. |
| Apple | We support to specify msg3 repetition. According to the simulation results, msg3 could be the bottleneck channel in many evulated scearios. Msg3 repetition could avoid unnecessary whole PRACH process re-transmission. |
| OPPO | We can introduce simple Msg3 repetition schemes. |
| CATT | We are in general fine with supporting Msg3 enhancements. In addition, we would like to clarify that only PUSCH repetition Type A is considered to make the scope clearer. Accordingly, we propose the following updates:  Specify mechanism to support PUSCH repetition~~s~~ Type A for Msg3 [RAN1] |
| NTT DOCOMO | Yes, since PUSCH of Msg3 is identified as the potential bottleneck channels for several scenarios, such as 4GHz rural scenario and FR2. |
| Nokia, NSB | We recommend supporting Msg3 and Msg1 enhancements, as those have fundamental impact on the actual cell radius within which UEs can access the network. It has been shown during the SI that legacy NR procedure can result in coverage shortage experienced by UE during msg1 and msg3 transmissions. Coverage of msg3 is impacted by the non-negligible payload size of this message, and by the absence of proper RRC connection which entails a lower antenna array gain at both UE and gNB. Indeed, currently msg3 transmission cannot enjoy all the features available for PUSCH when UE is in RRC\_CONNECTED, e.g., slot aggregation/repetition. |

Proposals:

* TBD

#### Potential PRACH Enhancements

Rappoetuer’s recommendation (as in RP-202360):

* [Specify PRACH enhancements for short formats for FR2 [RAN1, RAN2]]
  + Multiple PRACH transmissions with the same beam
  + Multiple PRACH transmissions with different beams

Questions:

* Would you recommend supporting PRACH enhancements for short formats for FR2? Why/why not?
  + Please elaborate detailed thoughts

|  |  |
| --- | --- |
| **Company** | **Views** |
| Samsung | Similar comments as above - PRACH was identified as bottleneck channels for FR2. Thus enhancement of PRACH is necessary.  PRACH enhancements with multiple same/different beams are beneficial to reduce the coverage imbalance between uplink/downlink, and also the latency of the overall random access procedure. We support to specify enhancements for PRACH for FR2 by introducing multiple PRACH transmissions with same or different beam(s). |
| Intel | We support to specify coverage enhancement for short PRACH format in FR2. However, given the overall scope and limited TU, it may be good to specify only “Multiple PRACH transmissions with the same beam”.  As captured in Table 5.2.2-1 in TR38.830, relative difference between PRACH format B4 PUSCH and reference channel, i.e., PUCCH format 1 in Urban 28GHz with O2I is 7.6dB. In our view, short PRACH format needs to be enhanced in order to meet the target requirement in FR2. |
| Panasonic | Yes, as it was bottleneck in some cases. |
| ZTE | We support PRACH enhancements for short formats for FR2.  Similar to multiple transmissions for other channels, multiple PRACH transmissions could provide clear joint decoding gain if the same beam is used, or finer beam sweeping gain if different beam is used. Legacy PRACH re-attempts cannot offer such gain due to unable for joint decoding at gNB side or unguaranteed beam sweeping.  The main concerns on supporting multiple PRACH transmissions is about the potential increased collision rate may neutralize the performance gain it offers. However, this highly depends on the detailed design. For instance, similar mechanism as discussed for 2-step RACH in Rel-16 can be reused, i.e., using separate ROs or preambles to differentiate between legacy UEs and enhanced UEs. With such design, the collision rate would not be increased, and therefore the gain from multiple PRACH transmissions could be obtained. |
| vivo | We don’t support PRACH enhancement. It was discussed in depth in RAN1 and critical issues raised were not addressed during SI. On top of that, since beam correspondence is mandatory feature in Rel-15, how does it fit with beam correspondence? In FR2, all channels do not meet target ISD, which means an operator has to consider to specific deployment scenario. FR2 is deployed for throughput, in this sense eMBB is the most pertinent channel, an operator will plan network deployment considering certain data rate in practice. |
| Apple | We are open to discuss whether PRACH format B4 is the bottleneck channel on FR2. According to FR2 simulation results, the standard deviation for PRACH format B4 is large, i.e., around 6dB, its MIL is worse about 2dB than the benchmark channel PUCCH format 1. And comparing with other potential bottleneck channels on FR2, PRACH format B4 is on the fringe of bottleneck. |
| OPPO | We support PRACH enhancement not specifically for FR2, could be for both FR1/2. |
| CATT | We prefer not to include PRACH enhancements considering the TU budget. |
| InterDigital | We are not supportive for the PRACH enhancement in general. Especially for the PRACH repetition with different beam, using different beams with PRACH repetitions won’t be helpful for coverage enhancement with beam correspondence. But, if the scope is limited to the PRACH repetition with the same beam, we may be ok to include PRACH enhancement in the WID. |
| Nokia, NSB | As mentioned above, we recommend supporting Msg3 and Msg1 enhancements, as those have fundamental impact on the actual cell radius within which UEs can access the network. It has been shown during the SI that legacy NR procedure can result in coverage shortage experienced by UE during msg1 and msg3 transmissions. Strong limitations exist in terms of actual antenna array gain at both UE and gNB during access, due to lack of advanced beam management features in RRC\_CONNECTED. Problem in FR2 deployments is further exacerbated by max TRP limitation of commercial UEs. Indeed, this situation already manifests itself in field deployments as well based on existing feedback.  Multiple PRACH transmissions with the same beam realizes link budget gain by allowing the same msg1 to be de facto repeated multiple times, while in case of Multiple PRACH transmissions with different beams, UE can sweep different Tx beams during the multiple msg1 transmissions and gNB can, for instance, determine the best beam pair and construct msg2 accordingly. Concerning the latter, it is worth observing that it is the only practically viable way to address the lower antenna array gain issue during access, due to absence of beam correspondence requirements prior to RRC connection establishment and due to the nature of analogue beamforming. Hence, those techniques are supporting different scenarios and FR ranges, thus implying both of them should be supported by the WID. |

Proposals:

* TBD

#### Any other channels?

Questions:

* Any other channels that you would recommend? Why?
  + Please elaborate detailed thoughts

|  |  |
| --- | --- |
| **Company** | **Views** |
| Intel | For NR CovEnh WI, we do not see the need to enhance any other channels. |
| ZTE | Broadcast PDCCH is also one of the bottleneck channels identified for FR1.  If coverage recovery for DL channels (e.g. Msg2/Msg4) are needed for RedCap UEs (e.g. if 1Rx is supported for TDD bands), it is preferable to specify corresponding coverage enhancements together with the consideration for broadcast PDCCH in this CE WI. |
| NTT DOCOMO | We prefer to consider broadcast PDCCH for the enhancement, sinc broadcast PDCCH is identified as one of 2nd priority bottleneck channels for FR1 (4GHz) with 24 dBm/MHz of BS Tx power. The baseline performance for 4GHz Urban scenario was studied with both 33 dBm/MHz of BS Tx power (derived by industry/market) and 24 dBm/MHz of BS Tx power (derived by actual NW operation). From the NW operator’s perspective, the practical parameters for the NW operation are essential for the coverage study. Therefore, both BS Tx powers should be considered for the potential bottleneck channel identification, and coverage enhancement for broadcast PDCCH with 24 dBm/MHz of BS Tx power should be considered. |

Proposals:

* TBD

### Other Aspects

#### Potential power boosting for pi/2 BPSK for PUSCH for PC2 UEs

Related RAN1 agreements/conclusion:

***Conclusion:***

* *RAN plenary to decide whether to support power boosting for pi/2 BPSK for PUSCH for PC2 UEs.*
  + [Specify power boosting for pi/2 BPSK for PUSCH for PC2 UEs [RAN4]]

Reference RP-202211 has some detailed proposals.

Questions:

* Do you recommend specifying power boosting for pi/2 BPSK for PUSCH for PC2 UEs? Why/why not?
  + Please elaborate detailed thoughts

|  |  |
| --- | --- |
| **Company** | **Views** |
| Samsung | The specification of power boosting for pi/2 BPSK for PUSCH for PC2 UEs can be handled completely in RAN4. As the proponent proposed in RP-202738, a separate work item would be considered in RAN4. |
| Vivo | This is closely related to UE hardware implementation, power boosting for PC2 UEs can be handled in RAN4. |
| China Telecom | We tend to agree with Samsung that a separate work item for “power boosting for pi/2 BPSK” may be a better choice as it has only RAN4 impact. |
| Apple | The performance of power boosting scheme was not extensive investigated during the study, only one simulation result was available. The impacts of this scheme are not minor, such as the possible new UE power class over 26dBm, transmission duty cycle, regulation restriction, impacts on UE PA implementation. All these issues are falling into RAN4’s work area, so we propose RAN4 to study whether to support the power boosting for pi/2 BPSK for PUSCH for PC2 UEs. |
| OPPO | No. Power boosting for one power class does not help for the overall coverage of network. |
| CATT | Similar view as Samsung. |
| Skyworks | Power boosting for shaped Pi/2 BPSK has already been covered by RAN4 for PC3 by enabling an equivalent of a negative MPR with a 3dB higher reference in power boosting mode. The same can be applied to PC2 and can be fully studied in RAN4 if required and should assume the use of low PAPR DMRS. For SAR and duty cycle aspects it could leverage the PC1.5 requirements since it would correspond to a similar case. |
| Nokia, NSB | We support the views expressed above by Samsung and others that the issue is better handled separately by RAN4 itself, include the potential studies. |

Proposals:

* TBD

#### Potential Interaction with NTN

Reference RP-202402 proposed to take into consideration of NTN to the extent possible in NR coverage enhancement work item, along with some detailed proposals.

Question:

* Do you recommend taking into account NTN in NR coverage enhancement work item (e.g., justification, objectives)? Why/why not?
  + Please elaborate detailed thoughts

|  |  |
| --- | --- |
| **Company** | **Views** |
| Samsung | The objectives of this WI will be based on the techniques that were studied in the SI phase and adding “NTN” in the justification would have no impact on the objectives. Even though the NTN use case has not been studied in the coverage enhancement SI, clearly NTN use case can benefit of the enhancements that will be specified in the coverage enhancement WI. It can be considered to add a statement to clarify that although we expect that the specifications will not differentiate between non-NTN and NTN (and in that sense, it may need to be further clarified what adding ‘NTN’ in the justification can provide if no additional specifications for NTN-specific enhancements are expected).  “Techniques for enhancing coverage specified in this WI can generally be used also for NTN use cases, however no additional work is done in this WI to ensure applicability of such techniques for NTN.” |
| Intel | In NTN SI, the link budget analysis shows:   * Link budget for DL is good enough (> -5 dB). * For UL GEO with handheld UE link budget is around -10 dB for for big antenna at the satellite and -15 dB for smaller antenna at the satellite * For UL LEO with handheld UE link budget is around -5 dB for big antenna at the satellite and -10 dB for smaller antenna at the satellite   In our understanding, the amount of coverage enhancement for NTN has been covered under CovEnh, and the features introduced under CovEnh can be applied for generic scenario (including NTN). Therefore, we do not think the clarification is needed under CovEnh WI, but it is okay for NTN WI to check if the features developed under CovEnh can be applied to NTN (i.e. applicability check). |
| Panasonic | NR coverage enhancement work item is not required to take into account NTN specific solution, but should be generic and applicable to NTN scenarios. |
| ZTE | We support to add NTN use cases in the justification of NR CE WI.  In satellite networks, uplink is also the coverage bottleneck, and the specified solutions in NR CE WI is not exclusive for only terrestrial networks. |
| vivo | CE WID objectives should not consider NTR scenario as it was not studied during SI phase. The techniques for coverage enhancement can be applicable to NTN as well, without expanding the scopes of WI. |
| SoftBank | It is no clear to us which channel(s) are bottleneck for which scnearios(GEO, LEO, HAPS, ATG) since this aspect was not covered by the study item. In this sense, RAN1 has no common understanding for NTN coverage enhancement, and hence we think we should stick to the scope of CovEnh WI optimized for terrestrial network and satellite terminals are allowed to import the CovEnh functionalities for terrestrial network. If more enhancements (or different functionality from that for TN) is required specifically for LEO/GEO scenarios, a separate discussion would definitely be necessary. |
| China Telecom | The objectives of the WID are based on the outcome of the study item. To be specific, all the enhancements included in the WID should be well studied. We understand that some technique can be beneficial for NTN scenario as well. We are fine to add the note as long as it does not have impact on the scope of the WID. |
| Apple | We are supportive to discuss this topic. Our understanding is that any specified coverage enhancement techniques can apply to NTN. |
| OPPO | A general enhancement on channels lik PUCCH would also help NTN coverage. |
| CATT | It is our understanding that coverage enhancement techniques specified in CE WI is not prohibited to be applied to NTN even of NTN scenario is not added in the WID. On the contrary, including NTN scenario explicitly in the WID may lead to the understandings that a different coverage enhancements target needs to be met, and/or compatibility of the CE technique and NTN need to be considered in the WI etc. Therefore, we prefer not to include NTN scenario in the WID. |
| InterDigital | We haven’t studied the bottleneck channel for NTN scenario during SI phase. Therefore, it is better not to include in the WID. In the end, the enhancement schemes can be potentially used for NTN as well but we don’t need to target NTN during the normative work. |
| Nokia, NSB | In our view most, if not all, techniques developed under coverage enhancements WID should be applicable to scenarios not directly considered during the SI phase, e.g. NTN. However, there has been no consideration on the specific aspects of NTN during the SI, and potential optimizations for NTN scenarios have not been discussed at all during the Coverage Enhancements SI. Hence, we do not find it feasible to extend the scope of the WID to include optimizations for NTN scenarios during Rel-17. |

Proposals:

* TBD

#### Any other specific aspects?

Question:

* Any other specific aspects that you would like to disucss? E.g., any other objectives that you’d like to recommend to be included in the work item? Handling of overlapped objectives with other WIs? Others?
  + Please elaborate detailed thoughts (particularly, if you have any preference regarding where/how to handle overlapped objectives with other WIs)

|  |  |
| --- | --- |
| **Company** | **Views** |
| Samsung | Regarding the potential overlap of Msg3 repetitions considered also in RedCap – this is a general solution for any NR UE that can be also applied to RedCap UEs. We think it should be specified in coverage enhancement WI, while RedCap WI may investigate aspects that are peculiar to RedCap UEs. |
| Intel | As described in our tdoc RP-202355, PUSCH-repetition-Type-B like PUCCH repetition and dynamic PUCCH repetition indication can be specified under either eURLLC/IIoT or CovEnh, potentially based on final scope size of CovEnh WI. Note that in this case it is important that the objective takes into account all technical requirements from eURLLC/IIOT, CovEnh, and Fe-MIMO. |
| ZTE | Considering the solutions studied in CE SI are generally common solutions and can be applied to CE UEs and RedCap UEs, we suggest including all potential coverage enhancement objectives in CE WI to avoid duplicated work.  For dynamic indication of PUCCH repetition factor, it has also been studying in Rel-17 IIoT/URLLC WI and FeMIMO WI. To avoid duplicated work, it is better to be specified only in one WI, e.g., CE WI. |

Proposals:

* TBD

# Conclusion

Based on the email discussion, the following are proposed:

* TBD

# References

RP-202211 Power aspects for pi/2 BPSK in Rel-17 Indian Institute of Tech (H)

RP-202267 Scope of Rel-17 WI on NR coverage enhancements Huawei, HiSilicon

RP-202302 Coverage Enhancement study and WI scope for Rel-17 OPPO

RP-202324 Views on the scope of Coverage Enhancement WI CMCC

RP-202352 Views on Coverage Enhancement WI Intel Corporation

RP-202355 On overlapping objectives across Rel-17 WIs Intel Corporation

RP-202360 New WID on NR coverage enhancements China Telecom

RP-202410 Views on WI for NR coverage enhancement Ericsson

RP-202527 Views on coverage enhancement WID scope NTT DOCOMO, INC.

RP-202530 On the scope of Rel-17 NR coverage enhancement Samsung

RP-202559 Views on NR coverage enhancements WI Apple Inc.

RP-202638 Views on WID scope for Rel-17 coverage enhancements vivo

RP-202665 Views on WID scoping for Rel-17 NR coverage enhancement ZTE, Sanechips

RP-202666 Views on Msg3 enhancement for Rel-17 NR coverage enhancement ZTE, Sanechips, Nokia, Nokia

Shanghai Bell, China Telecom, SoftBank, Thales, Sharp

RP-202680 Views on Coverage Enhancement WI in Rel-17 Nokia, Nokia Shanghai Bell

RP-202681 On the need for UL RACH enhancements in Rel-17 Nokia, Nokia Shanghai Bell, ZTE, Sanechips

RP-202694 Way forward on NR Coverage Enhancements MediaTek Inc.

RP-202711 Views on Rel-17 NR coverage enhancements CATT

RP-202738 New WID: Power aspects for pi/2 BPSK in NR IITH

RP-202745 Views on scope of NR Coverage enhancements WI Qualcomm Incorporated

RP-202402 NR Coverage Enhancement and NTN THALES, Qualcomm, Firstnet, Fraunhofer HHI, Fraunhofer IIS, Intelsat, Hughes Network Systems, ZTE, Panasonic, ESA, Oppo