**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. |
| Ericsson | **On overall scope**, the draft WID RP-202360 reflects quite a few possible objectives from the study item, and we think a reasonable study scope can only include a very limited number of the bracketed items that have small specification effort while providing substantial coverage benefit. |
| MediaTek | In general, we would like to prioritize PUSCH enhancement with clear RAN1 recommendations. Msg3 enhancement based on the generic PUSCH enhancement can be included as the low-hanging fruit.  The PUSCH enhancement should be generic and implicitly appliacable for RedCap/NTN devices. Besides, there is neither specific NTN/Redcap requirements in CE WID nor specific CE objectives under NTN/Redcap WIDs in Rel’17.  Besides, any channel enhancement with fundamental changes on the channel strcutrue are not preferred due to potential hardware impact. |
| Qualcomm | In our view, DL coverage enhancements (coverage recovery) should be included in RedCap, while the UL coverage enhancements should be in the CovEnh WI. |
| Sharp | CE SI studied general coverage issues. Identified potential coverage bottlenecks are not only for specific use cases such as RedCap. Therefore, we prefer that all the UL coverage enhancement objectives are included in CE WI and only RedCap UE specific items should be in RedCap WI. |
| ORANGE | We believe it is more logical to group all the coverage enhancement features within the NR Coverage enhancement WI and not in RedCap to avoid any potential overlap. |
| LG Electronics | Potential overlapping of work scope between work items should be avoided.  If it decides that msg3 PUSCH repetition is included in CE WI, it is not to include this scope in RedCap WI. |
| BT | Our view is that CE WI should include items agreed in CE SI as a priority given the consideration and discussion effort. However for features separately agreed for specification based on RedCap SI, it may be sensible to address the specification of closely related technical elements in one place. |
| EURECOM | To avoid overlapping, coverage enhancement for channels prioritized in CovEnh WI (PUSCH, PUCCH, potentially msg3 and PRACH) should not be studied also in other WI. RedCap WI and others, if necessary, could include coverage enhancement for additional channels specific to that WI not already included in CovEnh. |
| CMCC | Considering the limited TU and the outcome from SI, the enhancments of PUSCH should be prioritized. And the gap between PUSCH and PUCCH and other channel could be as much as 10 dB, the enhancements to the PUCCH and other channel cannot improve the real experience of users. The enhancements to PUCCH and other channels should be deprioritized.  The collisions or the overlaps between WIs should be avoided. |
| Huawei, HiSilicon | The enhancements for PUSCH with recommendations from RAN1 should be prioritized and included in the coverage WID. Among the remaining channels, more scenarios showing PUCCH as potential bottleneck channels, therefore some of the PUCCH enhancements can be considered also if justified.  The views on handling of overlap between different WIs can be seen in section 2.3.4.3. |

Proposals:

* To check the scope and potential overlappings after more stable discussion in the detailed objectives
  + Note: there seems to be a common understanding that a particular coverage enhancement technique (for DL or for UL) should be included only in one WI (either RedCap or CovEnh)

## 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(…)”* |
| Ericsson | This seems a reasonable starting point for the justification, and we agree that refinement may be in order after discussion of the objectives. |
| Qualcomm | We support including NTN in the justification section, as proposed in RP-202402. |
| BT | As we commented during CE SI definition phase, it is important that coverage enhancements lead to an enhanced overall system link budget. Therefore we support specification of multiple channels, and trust the group will select the appropriate combination of channels/messages towards that goal. |
| CMCC | Share similar view as Apple that the condistion for limitiation of Broadcast PDCCH should be notified. |
| SONY | Our general impression is that the objectives in the SI was defined in a way that set all focus on UL channels. However, we do see potential for improvement in particular for FR2 where enhancements on SSB will have significant impact on the performance. If the UE fails in the process of selecting the strongest beam pair, any enhancements in further communication may be wasted. |
| Huawei, HiSilicon | It is not necessary to list all the potential bottleneck channels in the justification section in the final version of the CE WID, instead only those (e.g. PUSCH) with specific objective(s) in the objective section can be listed here if really necessary.  Note that listing a channel as “potential bottleneck channel” here doesn't mean there is consensus in RAN1 that it is bottleneck channel. Based on RAN1 disucssion, a channel listed as potential bottleneck channel here might be drawn only based on the simulation results under some certain assumptions from a few companies. |

Proposals:

* The justification section in RP-202360 seems to be agreeable in principle. Updates are necessary particularly in terms of better reflecting the to-be-finalized objectives, along with other necessary refinements (e.g., whether or not to list all potential bottleneck channels (or at least clarifying the conditions for such bottleneck identification), past tense usage, potentially inclusion of NTN, potential addition of conditions for broadcast PDCCH, etc.)
* To update the justification after more stable discussion in the detailed objectives

## 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]

#### Initial Round

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. |
| Ericsson | We think the items recommended by the outcome of the study item, i.e. those not square bracketed in the Rapporteur’s recommendation above, are acceptable. However, they already bring significant specification effort. We therefore have the following suggestions:  **1.** **The two options for PUSCH repetition are redundant if we understand correctly. Our first preference is to specify Option 1,** as this has limited specification impact.   * Specify ~~one or two options for enhancement on~~ an increased number of repetitions, e.g. up to 32, for PUSCH repetition type A [RAN1]   Our second preference is to downselect among the two options, i.e:   * Specify one ~~or~~ of two options for enhancement on PUSCH repetition type A [RAN1]   **2.** **We suggest to remove the bracketed sub-bullet on sub-PRB allocation.** The results in RAN1 for the VoIP setup studied were mixed between showing relatively small gain when repetition is used as a baseline and having no gain. While sub-PRB may be appropriate for MTC use cases as a means to improve capacity for low data rate services while maintaining coverage, we do not think it is needed for the Rel-17 NR coverage enhancement work item, especially since LPWA services were excluded in the study item. Finally, sub-PRB has substantial specification impact, potentially including frequency and/or time domain resource allocation, TBS determination, DM-RS pattern, RV determination, hopping pattern within/between the PRBs, PUSCH signal generation for DFT-s-OFDM waveform, new RF requirements, and new power control. Adding sub-PRB would substantially increase the WI scope, possibly excluding other items, and this substantial increase is not justified given the limited (or in one observation, no) gains for the VoIP use case studied.  One alternative approach that is also acceptable in our view could be to omit the TB processing over multiple slots as well as sub-PRB, given its synergy with sub-PRB. This would leave more room in the WID for PUCCH and ‘other channel’ enhancement and allow sub-PRB to be specified along with multi-slot PRB in a future WI e.g. for LPWA.  **3. RAN1 should use RAN4 guidance while specifying joint channel estimation. Also, ‘consecutive’ may be misleading here, since RAN1 is looking for more general input from RAN4.** RAN1 asks in its LS to RAN4 R1-2009784 if back-to-back transmission is one of the conditions required for phase continuity, and the answer to this question should be taken into account in the Cov Enh work item. We suggest:   * + Specify mechanism to enable joint channel estimation [RAN1, RAN4]     - According to conditions and values for power consistency and phase continuity identified by RAN4, specify:       * Mechanism to enable joint channel estimation over consecutive PUSCH transmissions, including cross-slot channel estimation over at least 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] |
| Xiaomi | We are fine with the Rappoetuer’s recommendation for potential PUSCH enhancement and joint channel estimation.  We are open with the subitem for TB processing over multiple slots according to the time budget of NR CovEnh WI.  Regarding the sub-PRB transmission with multi-slot aggregation, we think it can be low priority considering the limited performance gain and relatively large spec impacts. |
| MediaTek | We are fine for the proposals which are aligned with RAN1 recommendation except for sub-PRB transmission. Considering no consensus in RAN1 and potential hardware/ChEst impact, it is not preferred for support of sub-PRB transmission in Rel’17. |
| Qualcomm | We support including all three main bullets. These are needed for both terrestrial networks and for NTN.  For PUSCH slot aggregation, at least Option 1 needs to be supported.  Regarding sub-PRB allocation, we believe it doesn’t provide any coverage gain. However, it can provide system resource savings, which could be useful for NTN, because the stallite link is expensive. But in our view, sub-PRB allocation can be downscoped if the overall scope is large.  Supporting cross-slot DM-RS bundling is essential for NTN, therefore it should be included. |
| Sharp | At least 3 items recommended in RAN1 should be included in WI. Sub-PRB can be also considered when time allows. |
| ORANGE | We are fine with the objectives. |
| LG Electronics | We are generally fine to include the three solutions recommended in the conclusion in TR. |
| BT | We support identified PUSCH enhancement mechanisms. However our view is that enhancements in other channels should take priority over PUSCH enhancements that have shown limited gain. |
| EURECOM | We also support identified PUSCH enhancement mechanisms. |
| CMCC | Generally fine with the recommendation from RAN1.  There is no consensus for the sub-PRB enhancements during the SI. The performance gain was not surfficently verified during the SI and the impact to the specification is high. Considerint there are at least 3 kinds of enhancements for the PUSCH, the need for the sub-PRB enhancements is not strong.  Since the TU is limited, we prefer to focus on one or two enhancements to the PUSCH. Considering the most TDD systems are uplink slot/resources limited, there are no additional uplink slots or resources for type A repletion. Then enhancements related with joint channel estimation and multiple slot TB processing should be prioritizes. |
| Huawei, HiSilicon | Agree with the recommendation from the rapporteur in principle. Two editorial/clarification comments as below:   1. Change the following bullet as below. According to the TR, joint channel estimation with/without optimization of DMRS location/granularity was studied, thus the recommendation “joint channel estimation” here should include specifying potential optimization of DMRS location/granularity in time domain and it is better to make it clearer in the objective.  * Mechanism to enable joint channel estimation over consecutive PUSCH transmissions with potential optimization of DMRS location/granularity in time domain, including cross-slot channel estimation over consecutive slots and joint channel estimation over multiple PUSCH transmission within one slot [RAN1]  1. “[Sub-PRB transmission with multi-slot aggregation]” is a separate enhancement discussed in RAN1, and according to the agreements in RAN1 it doesn’t belong to “TB processing over multi-slot PUSCH”. Therefore, it is better to list it as a separate bullet for further discussion, instead of listing it as an sub-objective under “TB processing over multi-slot PUSCH”. Suggest to modify as below:   =============   * 1. Specify mechanism to support TB processing over multi-slot PUSCH [RAN1, RAN4]      1. TBS determined based on multiple slots and transmitted over multiple integer slots. [RAN1]      2. ~~[Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]~~   2. Specify mechanism to enable joint channel estimation [RAN1, RAN4]      1. 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]      2. Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]      3. Specify the requirements for power consistency and phase continuity [RAN4]   3. [Specify sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]   ============   1. Suggest to do the following modification for joint channel estimation. The reason is that without the study from RAN4, it is not clear whether to define new requirements or just reuse the current requirements defined in RAN4, the original wording looks like for sure new requirements is needed.   Investigate and if needed specify the requirements for power consistency and phase continuity [RAN4] |

#### Intermediate Round

Summary from the initial-round discussion:

* Overall, it seems that the proposed objectives for PUSCH enhancements (except the one in brackets) are agreeable in principle, although there are various concerns
* For enhancement on PUSCH repetition type A
  + Samsung prefers option 2, while Ericsson prefers option 1 and proposes to specify option 1 only, or specify only of the two options. Qualcomm commented that at least option 1 needs to be supported
  + Given that there are different views, and the benefit of reduced scope, perhaps it is better to check whether we can specify only one of them
* Regarding “[Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]”
  + Current situation is:
    - Supported by: SierraWireless, Samsung, China Telecom, CATT, Huawei/HiSilion
    - Not supported by: Panasonic, ZTE, vivo, InterDigital, Nokia, NSB, Ericsson, Xiaomi (low priority), MediaTek, CMCC
    - Open to discussion (may depend on the overall scope and time budget): Intel, Apple (suggested to specify 6-tone only), Qualcomm, Sharp
  + Both OPPO and Huawei commented that “[Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]]” can be a separate subbullet
  + Given that there is a majority view on not supporting this bullet 🡪 suggest to remove it
* Others
  + CMCC prefers to focus on one or two enhancements to the PUSCH.
  + Vivo also expressed concerns over “TB processing over multi-slot PUSCH” in general. Ericsson mentioned the possiblity of remove “TB processing over multi-slot PUSCH”
  + CATT commented to remove the details for joint channel estimation to be aligned with the recommendation as capture in the TR, while Ericsson and Huawei proposed to add some additional details, including interaction with RAN4

Updated proposal:

* + Specify one ~~or~~ of the following 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(s) 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(s) to enable joint channel estimation [RAN1, RAN4]
    - Mechanism(s) to enable joint channel estimation over consecutive PUSCH transmissions, based on the conditions to keep power consistency and phase continuity to be investigated and specified if necessary by RAN4, ~~including cross-slot channel estimation over consecutive slots and joint channel estimation over multiple PUSCH transmission within one slot~~ [RAN1, RAN4]
    - Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]
    - ~~Specify the requirements for conditions to keep power consistency and phase continuity [RAN4]~~

Questions:

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

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | The proposal overall seems a good way forward. For joint channel estimation, we are still concerned with the word ‘consecutive’ in light of the LS to RAN4 R1-2009784 that asks ‘Whether back-to-back PUCCH or PUSCH repetitions is one of the conditions required to keep phase continuity cross the repetitions’. Suggest: ‘Mechanism(s) to enable joint channel estimation over multiple ~~consecutive~~ PUSCH transmissions, …’. |
| InterDigital | Regarding the downselection between options for PUSCH repetition type A, we want to keep it open whether we will down-select one of them or support both options as they are not exclusive each other. We can make decision in RAN1 based on the technical discussion during WI phase. Therefore, we prefer the original text in the draft WID. |
| Samsung | For PUSCH repetition Type-A, our preference is to discuss both options in RAN1 - OK to downselect in RAN1 if that is the only possible WF.  We would like to note that the only reason to even have this discussion is because PUSCH is not doing what PUCCH does (Option 2) since Rel-15 (due to reaching agreements in different sessions in Rel-15). A similar sentence for the PUSCH (Option 2) as the existing one for the PUCCH should be trivial to add without mandating a UE to support up to 32 repetitions.  For sub-PRB, we would request to keep it with lower priority and revisit it if time permits after strong progress is made on other items.  Fine with the third sub-bullet. |
| CATT | We are fine with the updated scope for PUSCH enhancements. Regarding the proposal from Ericsson, we would prefer to keep “consecutive” for now and we can further update based on RAN4 reply LS if needed given that the feasibility of joint channel estimation over non-consecutive PUSCH transmissions is not clear. |
| vivo | Although we expressed our concern TB processing over multi-slot PUSCH, the proposal in general is good way forward. We are also fine with specifying one of two options for PUSCH repetition. Regarding “consecutive PUSCH transmission”, we are ok with the wording as RAN4 will study the requirement of power consistency and phase consistency based on back-to-back transmission or not. |
| OPPO | The down-selection of option 1/2 is not needed. We can see if more companies accept.  We are fine for not support sub-PRB，no strong view.  When we accept the TB over multiple-slot in RAN1, our understanding is not limited to sub-PRB. Thus, if we assume PRB based, the time domaing resource differences, e.g. different number of UL symbols, still need enhanced TBS determination over multiple-slot.  The phase continuity seems should be “, based on the conditions if keeping power consistency and phase continuity is necessary and to be investigated and specified by RAN4,”  Others are fine for us. |
| Panasonic | We are fine with updated scope for PUSCH enhancement. On joint channel estimation, we support the suggestion from Ericsson. |
| Sierra Wireless | The proposal seems like a good way forward.  We are very support of downselection to only ONE option for PUSCH repetition type A.  We aggree with Ericsson’s concerns WRT the word ‘consecutive’ and would suggest this change: ‘Mechanism(s) to enable joint channel estimation over multiple ~~consecutive~~ PUSCH transmissions, …’. |

### 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]]

#### Initial Round

Questions:

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

|  |  |
| --- | --- |
| **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. |
| Ericsson | **Suggest to specify support for repetition of aperiodic CSI on PUCCH or PUSCH or dynamic indication of PUCCH repetition factor.** As discussed in more detail in RP-202410, using sequence based PUCCH (‘DMRS-less’) transmission and an advanced receiver for up to 11 bits does not improve performance over where advanced receivers are used for Rel-15/16 PUCCH. On the other hand, as observed in 38.830, repetition can bring 5 dB gain with 8 repetitions (without cross slot channel estimation), and so supporting repetition for aperiodic CSI on PUCCH or dynamic indication of repetition for PUCCH can be quite beneficial, while at the same time having relatively small specification effort. DMRS bundling for PUCCH is a logical second step, since it can bring e.g. 0.85 – 1.3 dB gain according to 38.830, and since further input is needed from RAN4 on the conditions where this can can be obtained. So while potentially useful, DMRS bundling for PUCCH is not so high a priority for these reasons, and may moreover be hard to squeeze in given other objectives. Type B-like PUCCH repetition is mainly for short PUCCH enhancement which is not as clearly beneficial to us, especially given the specification impact and the fact that a long PUCCH format can be used with repetition. |
| Xiaomi | We think one or two solutions should be mainly considered and have high priority considering the TU shortage. Furthermore,we recommend that different solutions for short PUCCH or long PUCCH should be discussed and limited sperately. For example, we think PUSCH-repetition-Type-B like PUCCH repetition is more suitable for short PUCCH format enhancemen whilt DMRS-less and DMRS bundling across PUCCH repetitions can be limited to long PUCCH. |
| MediaTek | Supposing PUSCH and msg3 enhancments will be part of the scope, there are no sufficient TUs for PUCCH enhancement especially to cover all listed solutions. In FR1, PUCCH is listed as the bottleneck channel only in one scenario (with similar performance as PUSCH). So if necessary to handle it under CE WI, the PUCCH enhancement should be simple and efficient to avoid any over-design, e.g., only solution 3 (dynamic PUCCH repetition factor indication). On the other hand, PUCCH enhancments can be discussed/handled under the other topic (e.g., MIMO) considering the balance between UL high rank feedback and DL MIMO transmission. |
| Qualcomm | We support including at least the following:   * DM-RS-less PUCCH * DM-RS bundling for slot aggregation   In terrestrial networks, where DL slot aggregation is often not needed, PUCCH slot aggreagation doesn’t improve coverage because for HARQ ACK UCI, the payload linearly increases with increasing the number of aggregated PUCCH slots. Therefore a different method is needed that doesn’t rely on slot repetition. The only such method identified is DM-RS-less PUCCH.  Note that consistent gains were observed with DM-RS-less PUCCH by the majority of companies evaluating it. We would like to note that the Intel evaluation didn’t consider the agreed limit on undetected error rate per our understanding.  PUCCH slot repletion and DM-RS bundling is still important for NTN, where both UL and DL slot aggregation is expected to be used, therefore increasing the aggregated PUCCH slots here does not increase the PUCCH payload. |
| Sharp | We support DMRS-less PUCCH. Majority of sources showed the performance gain. |
| ORANGE | We believe DMRS-less PUCCH should be specified. This is one of very few techniques allowing to improve the UL coverage without relying on repetitions. |
| LG Electronics | If PUCCH is identified as a coverage bottleneck, we are fine to include PUCCH enhancement as a work scope in CE WI. We prefer 3rd and 4th solutions rather than 1st (DMRS-less) and 2nd (PUSCH-repetition-Type-B like PUCCH). It seems that the benefit of 1st solution is controvesal so far. |
| BT | We agree with China Telecom and Softbank that PUCCH enhancements are needed. We do not have a strong preference on exact solution. We however can add that DMRS-less PUCCH are widely used in the field, and we expect enhancements to this approach will be beneficial. |
| EURECOM | We strongly support DMRS-less PUCCH. It was the technique showing the most promising result in terms of coverage enhancement in the SI and the one with most sources showing improvements (7 or 8 companies reporting significant gains). |
| CMCC | Since the coverage gap between PUSCH and PUCCH is almost 10dB, we do not see much motivation to enhance PUCCH while PUSCH is still limited and cannot satisfied the requirements.  Based on the evaluation results captured in our contribution at this meeting, the gain of the DMRS less PUCCH is not much. More discussions about the using scenarios and justifications are need. |
| Huawei, HiSilicon | We recommend to include DMRS-less PUCCH in the WID scope with modification as below:   * + Specify DMRS-less PUCCH with new sequences for UCI payload up to 11 bits [RAN1, RAN4]   The reasons are given as below:   1. Based on the simulation results captured in section 6.2 in the TR, among the 4 candidate mechanisms for PUCCH enhancements, DMRS-less PUCCH with **new sequences** is able to provide very promising gain with lower complexity receiver, e.g. more than 2dB gain compared to the existing PUCCH format 3.   **New sequence is very critical for DMRS-less PUCCH**. Firstly, new sequence enables low-complexity receiver as shown in R1-2009747, lower complexity receiver is very important from implementation perspective. Secondly, even with low-complexity receiver, the new sequence can provide comparable gain compared to existing sequence with high-complexity receiver, as shown in section 6.2.1 in the TR. Thirdly, DMRS-less PUCH with existing sequence (e.g. CGS, gold, ZC, etc) requires high complexitgy receiver, and provides very small gain compared to PUCCH format 3 with high complexity receiver as observed in some contributions, e.g. R1-2009737 as shown in section 6.2.1 in the TR. Therefore, only with new sequence as shown in R1-2009747 (i.e. Reed-Muller sequence), specifying DMRS-less PUCCH is meaningful. |

#### Intermediate Round

Summary from the initial-round discussion:

* Whether or not specify PUCCH enhancements?
  + Supported by: Sierra Wireless (only one solution), Samsung, Intel, Panasonic, ZTE, vivo, SoftBank (msg3 PUSCH has a higher priority), China Telecom (one or two solutions), OPPO, CATT (no more than two), NTT DoCoMo, InterDigital, Ericsson, Xiaomi (one or two solutions), Qualcomm, Sharp, ORANGE, LGE, BT, EUROCOM, Huawei/HiSilicon
  + Not supported by: Nokia/NSB, MediaTek (assuming PUSCH + msg3 specification), CMCC (do not see much motivation)
* Detailed techniques:
  + Note: Nokia/NSB, MediaTek, CMCC’s names are not listed in each of the technique below for “not supporting”, since we have already have on the above general bullet
  + [Specify DMRS-less PUCCH with UCI payload up to 11 bits [RAN1, RAN4]]
    - Supported by: ZTE(may be only for long PUCCH), OPPO, InterDigital (may be only for long PUCCH), Qulaocmm, Sharp, ORANGE, BT, EURECOM, Huawei
    - Not supported by: Intel, Ericsson (prefers supporting repetition)
    - Open for more discussion: Panasonic (frequency and timing error), Apple, CMCC (using scenarios and justifications)
  + [Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]]
    - Supported by: Samsung, Intel (maybe under URLLC), vvio, Xiaomi (short PUCCH)
    - Not supported by: Panasonic, CATT, Ericsson
    - Open for more discussion: Apple (may be under URLLC), OPPO (certain conditions)
  + [Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]]
    - Supported by:Samsung, Intel (maybe under URLLC), Panasonic (maybe under URLLC), ZTE, Apple, OPPO, CATT, Ericsson, LGE
    - Not supported by:
  + [Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]]
    - Supported by: Samsung, Intel, Panasonic, vivo, OPPO, InterDigital, Xiaomi (long PUCCH), Qualcomm, LGE, Ericsson (as a secondary choice and if time allows)
    - Not supported by: ~~Ericsson~~
  + Others:
    - Ericsson proposed to specify support for repetition of aperiodic CSI on PUCCH or PUSCH

It seems that there is a clear majoritity of companies prefers to specify at least one PUCCH enhancements, while the detailed enhancement(s) seem controversial. There are also quite a few companies proposing to specify no more than two mechanisms. The following is thus proposed:

Proposals:

* Specify at least one mechanism (but no more than two) PUCCH enhancement mechanisms
  + All companies are encouraged to provide their views on:
    - 1st preference of PUCCH enhancement mechanism
    - 2nd preference of PUCCH enhancement mechanism
* Additional thoughts are welcome

Please share your thoughts about the above proposal below.

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | Presuming that there are enhancements for the ‘other’ channels (e.g. Msg3 and/or PRACH), we think that there will be insufficient time for more than 1 PUCCH enhancement. If a second PUCCH enhancement is considered, it should be ‘low hanging fruit’, such as DMRS bundling (since bundling seems already agreeable for PUSCH). Furthermore, if PUCCH enhancement is covered by another WI, then having all PUCCH enhancements in that other WI rather than Cov Enh seems preferable, since that will help with the high amount of work we may have in Cov Enh.  Our preferences are:  1st preference: Dynamic PUCCH repetition factor indication or A-CSI (with repetition) on PUCCH  2nd preference: DMRS bundling across PUCCH repetitions (Please note where we clarify this in the summary text above with change marks) |
| InterDigital | In general, we are ok with this direction for the progress. Here are our preferences:   * 1st preference: DM-RS less PUCCH with UCI payload up to 11bits * 2nd preference: DM-RS bundling across PUCCH repetitions |
| Samsung | The last 3 mechanisms would be rather simple to specify and implement – there is no apparent TU or complexity concern to justify absence for any of those mechanisms for CovEnh.  First preference: Dynamic PUCCH repetition factor  Reason: Rel-16 mechanism is problematic, no issue with gNB/UE implementation complexity (even eMTC UEs support dynamic PUCCH repetitions although the exact mechanism in NR can be different).  Second preference: PUSCH-repetition-Type-B like PUCCH  Reason: Already supported for PUSCH, minimizes latency and improves data rates. Rel-17 MIMO agreed to support intra-slot repetitions to improve coverage for multi-TRP, would not make sense to not support for single TRP.  Third preference: DMRS bundling across PUCCH repetitions  Reason: Can improve coverage, trivial for network to support, also considered for PUSCH - additional specification/RAN1 impact is expected to be minimal. |
| CATT | 1st preference: dynamic PUCCH repetition factor indication  2nd preference: DMRS bundling across PUCCH repetitions  It is understood that which WI the PUCCH enhancements to be included may be subject to other discussions, e.g. email thread #[26]. |
| vivo | We are ok with at least one PUCCH enhancement. Our preferences are as follows:  1st preference: Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition  2nd preference: Specify mechanism to support DMRS bundling across PUCCH repetitions |
| OPPO | We need enhance the channel based on the study. Enhancing only PUSCH with out PUCCH make it incomplete. As a way out, we have to choose:   * 1st preference: DM-RS less PUCCH with UCI payload up to 11bits * 2nd preference: Dynamic PUCCH repetition factor indication |
| Panasonic | We are OK with at least one PUCCH enhancement. Our preference is as follows.  1st preference: Specify mechanism to support DMRS bundling across PUCCH repetition. |
| Sierra Wireless | 1st preference: Dynamic PUCCH repetition factor indication |

### 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]]

##### Initial Round

Questions:

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

|  |  |
| --- | --- |
| **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. |
| Ericsson | **While not a high priority, Msg3 repetition can be specified.** In our understanding, HARQ can provide good coverage for Msg3. However, HARQ for Msg3 requires more PDCCH overhead, and given that Msg3 repetition should be relatively straightforward to specify, we think it is OK to include in the WID. |
| MediaTek | We support Msg3 enhancement based on repetitions which can be the low-hanging fruit of PUSCH enhancement. It is benefical for the coverage of the large Msg3 payload size. |
| Qualcomm | We support introducing Msg3 repetition. This is important for NTN and also for FR2. |
| Sharp | Recommend. Msg3 PUSCH is identified as potential coverage bottleneck in FR1 and FR2, It is also identified as the potential coverage bottleneck based on service dependent target for VoIP. Majority of companies indicated support for msg3 PUSCH repetition in the last RAN1 meeting.  It is also clear that the coverage problem for Msg3 PUSCH is not only for RedCap Ues. Therefore, we support to include enhancement for Msg3 PUSCH repetition in CE WI. |
| ORANGE | We support. |
| LG Electronics | It seems that coverage enhancement of msg3 PUSCH is necessary. Also, msg3 PUSCH coverage ransmissio is proposed in the scope of RedCap WI. It need to be clarify whether msg3 PUSCH enhancement is included in CE WI or not. |
| CMCC | Similar as the enhancements to the PUCCH, Msg 3 have a much better coverage performance than PUSCH, we do not see any urgency or motivation to enhance Msg 3. Besides that, Msg 3 have the re-transmission mechanism, the repetition only solve the latency issue not the coverage. |
| Huawei, HiSilicon | There is overlapping between coveage WI and Redcap WI on Msg3 enhancments, the handling of overlap needs to be discussed first in order to decide whether/how to include an objective here.  For normal eMBB UE, we feel it is not useful to do PUSCH repetition for Msg3.   1. The existing mechanism supports retransmission of Msg3 PUSCH, which can help improve the performance. 2. The packet size for Msg3 PUSCH is very small, e.g. 56 bits, which corresponds to 56 kbps date rate. A real useful network would be able to provide a much higher average date rate, which means that Msg3 PUSCH performance should not be a problem in real eMBB network. 3. In real network, network deployment needs to consider Msg3 PUSCH for Rel-15/16 UE also, that is network has to be deployed to ensure full coverage for Rel-15/16 Ues also, therefore Msg3 PUSCH repetition for Rel-17 Ues is not really helpful in real network deployment at least from cell density perspective. By the way, this is different from enhancements for other channels, e.g. PUSCH, since different date rate between Ues of different release would be achived and their coverage shortage compared to Msg3 can be compensated. 4. Msg3 PUSCH is identified as potential bottleneck channel only for the following scenarios based on results from some sources:    1. 28GHz TDD NLOS O2I scenario: As shown in Table 5.2.1.1-3 in the TR, the gap from 200m ISD requirement for both PUSCH eMBB and PUSCH of Msg3 is too big, e.g. ~ -31.72 for PUSCH eMBB DDDSU and ~ -19.57 for PUSCH of Msg3, therefore even with the repetition of PUSCH Msg 3 and the potential enhancements of PUSCH eMBB, it is very difficult to meet the requirement for this scenarios.    2. Rural 4GHz TDD NLOS O2I scenario: As shown in Table 5.1.1.3-3, the gap from the requirement of deployment dependent target 3000m ISD for both PUSCH eMBB and PUSCH of Msg3 is also very big, e.g. -16.27 for PUSCH eMBB and ~-11.12 for Msg3 PUSCH, and thus similar as above repetition here is not that helpful.   Rural 700MHz FDD NLOS O2I scenario: As shown in Table 5.1.1.6-3, the gap from deployment dependent target exists only in case of 4000m ISD and is very small of Msg3 PUSCH, e.g. -0.6dB, in this case the existing mechanism of retransmission can work well. |

##### Intermediate Round

Summary from the initial round discussion:

* [Specify mechanism to support PUSCH repetitions for Msg3 [RAN1]]
  + Supported by: Sierra Wireless, Samsung, Intel, Panasonic, ZTE, vivo, SoftBank, ChinaTelecom, Apple, OPPO, CATT, NTT DoCoMo, Nokia/NSB, Ericsson, MediaTek, Qualcomm, Sharp, ORANGE, LGE,
  + Not supported by: CMCC (do not see any urgency and motivation), Huawei
* CATT also proposed to clarify that it’s only for PUSCH repetition type A

It seems that there is a clear majority to support msg3 repetition. The following is thus proposed:

Proposal:

* Specify mechanism(s) to support Type A PUSCH repetitions for Msg3 [RAN1]]
  + Further discuss how to handle potential overlapping with RedCap

Please share your thoughts about the above proposal below.

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | Support the proposal, provided that the WI scope is not too large. Msg3 is not a high priority in our view given coverage gains already possible from Rel-15 Msg3 retransmission, so Msg3 repetition can be omitted if necessary to control the WI scope. |
| Samsung | We agree with the original version of the proposal - do not agree with the limitation for “typeA” - it is currently unnecessary. Slot-based repetitions are not efficient and would increase latency in TDD. This should be part of RAN1 discussions given that Rel-16 supports both Type-A and Type-B repetitions. |
| CATT | We support the proposal. Given the comments from Samsung, it seems important to have a clear understanding whether PUSCH repetition type B is included for Msg 3. In the SI phase, only PUSCH repetition type A was studied as captured in the TR (copied below) so that we don’t think PUSCH repetition type B should be included.   |  | | --- | | Enhancements on Msg3 PUSCH repetition were studied from several aspects, including the indication of the number of repetitions for Msg3 initial transmission and re-transmission, the repetition type, the feasibility and applicability of enhancements studied for PUSCH in RRC\_CONNECTED state for Msg3 PUSCH initial and re-transmission, inter-slot frequency hopping and differentiation between enhanced UE and legacy UE.   * Potential specification impacts of indication of the number of repetitions for Msg3 initial transmission include:   + Explicit indication mechanism, e.g., indicated by RAR UL grant, DCI format 1\_0 with CRC scrambled by RA-RNTI or SIB1.   + Implicit indication mechanism, e.g., determined by PRACH configuration or information carried by RAR. * Potential specification impacts of indication of the number of repetitions for Msg3 re-transmission include:   + Explicit indication mechanism, e.g., indicated by DCI format 0\_0 with CRC scrambled by TC-RNTI.   + Implicit indication mechanism, e.g., determined by Msg3 initial transmission. * Potential specification impacts of the repetition type include:   + Introducing PUSCH repetition Type A. * Potential specification impacts of the feasibility and applicability of enhancements studied for PUSCH in RRC\_CONNECTED state for Msg3 PUSCH initial and re-transmission include:   + The potential specification impacts for the solutions studied in Section 6.1. * Potential specification impacts of inter-slot frequency hopping include:   + Inter-slot frequency hopping configuration and frequency hopping pattern. * Potential specification impacts of differentiation between enhanced UE and legacy UE include:   Mechanism to differentiate enhanced UE and legacy UE, e.g., separate PRACH configurations (e.g, separate PRACH occasions or preambles) and separate Msg3 configurations (e.g., separate DMRS ports). | |
| vivo | We are supportive of the proposal, one comment on revised text “mechanism(s)”, wondering whether the intention is to specify multiple techniques. |
| OPPO | We support the proposal. |
| Panasonic | We support the proposal. |
| Sierra Wireless | We support the proposal. |

#### 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

##### Initial Round

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. |
| Ericsson | **Given recent feedback from operators and other manufacturers, we are open to further discussing this enhancement.** In our understanding, the proposal is that multiple Rel-15/16 PRACH transmission is proposed, since PRACH signal design and slot structure do not need enhancement to enable multiple PRACH transmission. This should be clarified. |
| MediaTek | We prefer no inclusion of PRACH enhancement in CE WI. Considering the limited TUs, we’d better focus on the FR1/FR2 common bottleneck channels. Since a set of channels in FR2 are problematic for coverage, PRACH-only enhancement doesn’t help the coverage of the whole system. If necessary, PRACH enhancement could be discussed/handled in the other topic whereas the CE WI can only focus on the FR1/FR2 common bottleneck channels. |
| Qualcomm | We support including PRACH enhancements, at minimum, same beam repetition should be supported. The main purpose of this is to enable a P3-like process at the gNB based on PRACH, the result of which can be used both for Msg2 transmission and Msg3 reception. Without PRACH based beam refinement, the beamforming gain during access would remain limited, which was identified as ransmissi in FR2. |
| Sharp | Recommend. PRACH format B4 is identified as potential coverage bottleneck in FR1 and FR2. Majority of companies indicated support for multiple PRACH transmission within RAR window in the last RAN1 meeting. |
| LG Electronics | So far, it seems controversial whether PRACH format B4 is the bottleneck channel on FR2. But, if PRACH format B4 is identified as bottleneck, and specification of PRACH enhancement on FR2, we prefer to capture ‘Multiple PRACH transmissions with the same beam’ only in the WID. |
| CMCC | Similar as the enhancements to the PUCCH, Msg 3 have a much better coverage performance than PUSCH, we do not see any urgency or motivation to enhance Msg 3. Besides that, Msg 3 have the re-transmission mechanism, the repetition only solve the latency issue not the coverage. |
| Huawei, HiSilicon | We have concern with PRACH enahncements for short formats for FR2. No recommendation on this was achieved in RAN1. The current study of PRACH enhacements in Rel-17 CE SI is not sufficient to justify an objective for it.   1. The evaluations in Rel-17 CE SI as captured in the TR was done assuming initial RPACH transmission for the performance evaluation, while the existing mechanism actually supports more transmissions for PRACH. Since there is no evaluation taking into account more transmission for PRACH, it is not clear whether PRACH is bottleneck channel or not, we cannot make the decision only based on the simulation for initial PRACH ransmission. 2. Rel-17 CE SI didn’t study the impacts that PRACH repetition will bring, e.g. the impact from collision due to PRACH repetition. Thus, it is difficult to judge whether supporting PRACH repetition is helpful or not. |

##### Intermediate Round

Summary of discussion from the initial round:

* [Specify PRACH enhancements for short formats for FR2 [RAN1, RAN2]]
  + Multiple PRACH transmissions with the same beam
  + Multiple PRACH transmissions with different beams
* Supported by: Samsung, Intel (maybe only same beam), Panasonic, ZTE, OPPO (can be for FR1 as well), Nokia/NSB, Qualcomm (at least same beam), Sharp (format B4 for FR1 & FR2), LGE (only same beam)
* Not supported by: vivo, MediaTek, CMCC (do not see any urgency or motivation), Huawei
* Open for discussion: Apple (PRACH format B4), CATT, Ericsson

While there is some majority of supporting PRACH enhancements for short formats for FR2 (particularly for the same beam case), 8 supporting companies vs. 3 non-supporting companies vs. 3 open for further disucsion, considering the overall scope and time budget, the following is proposed:

Proposal:

* To discuss further:
  + Alt 1: Specify PRACH enhancements for short formats for FR2 [RAN1, RAN2]]
    - Multiple PRACH transmissions with the same beam
  + Alt 2: No support of specifying PRACH enhancements for short formats in this work item

Please share your thoughts about the above proposal below.

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | Except for dynamic PUCCH repetition factor and/or A-CSI (including repetition) on PUCCH and for DMRS bundling for PUCCH, we see more potential benefit from multiple PRACH transmission than for PUCCH enhancements. As a way forward, we can accept Alt. 1 provided that the scope of the WI is not excessive, and where dynamic PUCCH repetition, A-CSI (including repetition) on PUCCH, or DMRS bundling for PUCCH is specified (either within CovEnh or another WI). |
| InterDigital | We are ok with Alt-1 for the progress. |
| Samsung | We prefer Alt1. If the reason to exclude different beams is due to UE complexity concerns, it is noted that NR UEs are already capable of beamsweeping in connected mode |
| CATT | We are fine with the proposal which is a step further. Between the two alternatives, we prefer Alt 2. |
| vivo | Our preference is Alt 2. On one hand, the scope of WI is getting big, on other hand from evaluation during SI the gap for given PUSCH data rate is around 20dB, FR2 is deployed for throughput, PUSCH is still the bottleneck even with reduced PUSCH data rate. |
| OPPO | Alt 1. We need make decision here. |
| Panasonic | We are fine with the proposal and our preference is Alt.1. |

#### Any other channels?

##### Initial Round

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. |
| Ericsson | **Suggest to support repetition for A-CSI on PUSCH as well as PUCCH.** Given that CSI is a bottleneck and that CSI on PUSCH should have similar coverage to CSI on PUCCH (we actually saw somewhat worse coverage for CSI on PUSCH in our evaluations), CSI coverage should be enhanced for PUSCH as well as PUCCH. Since repetition for aperiodic CSI on PUSCH is not supported in Rel-15/16, the Cov Enh work item is the most logical place to do so. Then for PUCCH, aperiodic CSI (with repetition) or dynamic indication of PUCCH repetition can be supported to provide the same coverage for both PUSCH and PUCCH while avoiding excessive overhead. |
| MediaTek | No need of any other channel enhancement. |
| Qualcomm | Msg2 PDCCH is a bottleneck in FR2. But at least if PRACH repetition with the same beam is supported, the gNB can use refined beam for Msg2 PDCCH, which should help solving the Msg2 PDCCH problem. |
| SONY | SSB enhancements can potentially improve FR2 beam pair selection during initial access. We propose to prioritize this in the scope of the WI. |

##### Intermediate Round

Based on the discussion during the initial round, it seems that while there are some desire to further specify a few aspects for coverage enhancements, there are also companies who clearly indicated that there is no such a need.

Therefore, it is proposed to not discuss any further.

### 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.

##### Initial Round

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. |
| Ericsson | Similarly to other companies, we think the proposal is RAN4 related and it could be further studied in e.g. RAN4. |
| MediaTek | There seems no sufficient study in SI since the evaluation/study from RAN4 is missing. It can be discussed in RAN4 and handled in the other WI than CE WI, if necessary. |
| Qualcomm | Power boosting, if feasible, can provide important enhancement for coverage. Therefore, we support considering this technique in general. However, the achievable power boost may be somewhat less than 3dB, since the supported maximum power does not only depend on PAPR.  We believe that the feasibility and achievable power boost needs to be established in RAN4. Given that this has not been studied in detail yet, perhaps a separate SI could also be considered. |
| CMCC | Similar to the other companies. There is not sufficienct study during the SI. And it seems more related with RAN4. |
| Huawei, HiSilicon | 1. For power booting for pi/2 BPSK, RAN4 should be involved to study the feasibility, if it will be included here there should be a study phase in RAN4 first. 2. As to the proposal for setting a new power class for pi/2 BPSK, it was not studied in RAN1 coverage SI. Similar as the above bullet, RAN4 should be involved to study the feasibility also, then based on RAN4 study and if possible can follow the previous approach to define the additional power boosting on top of the existing power classes to meet the operator requirements. In general, we think power class should be independent of a modulation order. |

##### Intermediate Round

Based on the initial round of discussion, it seems that a majority of companies suggested for a separate study in RAN4 (Samsung, vivo(?), China Telecom, Apple, CATT, Skyworks(?), Nokia/NSB,. Ericsson, MediaTek, Qualcomm, CMCC(?), Huawei), although OPPO indicated no support of specifying power boosting for pi/2 BPSK for PUSCH for PC2 UEs

The following is proposed:

Proposal:

* No additional discussion on “specifying power boosting for pi/2 BPSK for PUSCH for PC2 UEs” in the coverage enhancement WI
  + Proponents are encouraged to discuss further as a separate RAN4 item

Please share your thoughts about the above proposal below.

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | Support the proposal |
| CATT | Support the proposal |
| vivo | We support the proposal |
| OPPO | We are fine with the proposal by majority view. |

#### 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.

##### Initial Round

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 NTN 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. |
| Ericsson | **NTN can reuse mechanisms identified within the scope of the Cov Enh study without affecting the Cov. Enh work item.** Our view is that enhancements to be specified for Cov Enh should be determined by use cases identified in the Cov Enh study item. However, enhancements that are suitable for NTN can also be used for NTN, that is, the NR Cov Enh scope should not grow to include NTN specific requirements. Adding NTN specific investigations and simulations would dramatically expand the workload, and such parallel investigation within Cov Enh and NTN will likely be quite inefficient. |
| MediaTek | There is no need of NTN specific requirements/enhancement in CE WI since it is not part of CE SI. However, we can focus on the generic enhancement solution to implicitly applicable for NTN devices. |
| Qualcomm | We strongly support including NTN aspects. It is sufficient to include NTN in the jujustification section as proposed in RP-202402, and separately consider if any of the objectives need NTN specific update.  In our assessment, adding NTN-specific objectives may not be necessary as long as at least the following are specified in Rel-17   * PUSCH repetition with more than 16 slots * TBS targeting multi-slot transmission * PUSCH DM-RS bundling * PUCCH DM-RS bundling * Msg 3 repetition   In our view, without the above, satellite communication would only be possible with handheld devices equipped with external antennas, similar to existing satellite phones, but not with smartphones with internal antennas. |
| ORANGE | Techniques developed within the NR coverage WI could also apply for NTN. |
| LG Electronics | We are fine to consider NTN scenario in CE WI. |
| CMCC | The output from CE WI could benefit the NTN scenario, since the solution from the CE WI should be applicable to all sencarios.  But there is not eough study on the NTN coverage issue, such as which channel is the most limited and how much are needed for the enhancements. We do not prefer to rush into the enhancements and without any detailed studies. We also believe there are also spaces to develop NTN specific soltions beside the general CE solutions.  We support the NTN study and encoverage the solutions to the NTN coverage issues. But we hesitate to rush into CE WI involving NTN issues and without any detailed study. |
| Huawei, HiSilicon | There is no need for a specific clarification for NTN in the WID objectives or justification section, since it should be understood that the enhancements in Coverage WI would also be applicable to NTN. This should be the understanding for any WI, not only coverage enhancements. If the objectives derived from the study on coverage for terrestrial networks are already deemed sufficient for NTN then the discussion can be closed. Otherwise a similar study for NTN would be needed.  The coverage enhancement study has not considered NTN scenarios, so normative work as outcome of the study can only target to solve problems that are specific to terrestrial networks. If coverage issues specific to NTN are identified in another study (or as part of the NTN WI) and justified by RAN1, then corresponding objectives could be included in this WI or another WI. But no such study has been conducted so far.  In addition, it is expected that it would be very challenging for this release to do enhancements specific targeting at NTN. The simulation assumptions for NTN would be quite different from what we did in coverage SI, such as deployment secnearios, channel model, device characteristic, etc. Therefore, RAN1 would need to do all the evaluations again to identify which channel(s) needs to be enhanced specific for NTN, it can be expected the workload is high. |

##### Intermediate Round

Based on the initial round of discussion, it seems that all companies in general understand that all the coverage enhancements developed in this WI would be general applicability, including NTN. However, it was also pointed out that coverage enhancements specific to NTN were not studied during the study phase. There are concerns that enhancement specific to NTN in this work item may increase its scope.

The following is thus proposed:

Proposal:

* Add in the justification:
  + It is noted that during the study phase, while it was not explicitly studied NTN-specific coverage issues and enhancement techniques, it is understood that the enhancement techniques herein are applicable to NTN scenarios as well.
* No specific optimization of coverage enhancement techniques for NTN in this work item

Please share your thoughts about the above proposal below.

|  |  |
| --- | --- |
| **Company** | **Views** |
| Ericsson | Suppor the proposal |
| InterDigital | Support the proposal |
| Samsung | We would like understand why NTN, and not other verticals (e.g. REDCAP), is to be added when no specific optimizations are targeted. The specifications would not preclude applicability. UE features discussions can then consider what is to be supported for each vertical. Basically, what is lost by not adding the suggested text? If any clarification is needed, the following may be considerd   * It is noted that techniques for enhancing coverage specified in this WI are also applicable for NTN use cases; however no additional work is done in this WI to ensure applicability of such techniques for NTN.” |
| CATT | Support the proposal |
| vivo | We support the proposal |
| OPPO | The proposal does not essentially change the objectives. So, the proposal of objective parts is OK. But, it ask put the justification should also consider NTN scenarios. We still need that discussion. |
| Panasonic | We support the proposal. |

#### 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. |
| Ericsson | **Regarding interaction with other WIs**, we understand there can be some overlap with URLLC/feMIMO on dynamic PUCCH repetition or aperiodic triggering of repeated CSI on PUSCH/PUCCH. We do not have a strong view on where either of these are specified, but if either or both of these PUCCH enhancements are specified outside of the Cov Enh WI, then further PUCCH enhancements are not needed in Cov Enh, which can help with its scope. Similarly multi-TRP within feMIMO could cover dynamic PUCCH repetition, however the feMIMO use cases are more specialized to adding multi-TRP support over different PUCCH repetitions, and in our expectation this can be supported on top of what Cov Enh first specifies. Lastly, for RedCap, with the complexity reduction techniques in the proposed WID (RP-202701), only PUSCH and Msg3 in FR1 require coverage recovery in our view. Therfore, solutions to be specified for NR Cov Enh can be sufficient for RedCap coverage recovery. **In summary**:   * Dynamic PUCCH repetition and/or aperiodic triggering of repeated CSI on PUSCH/PUCCH can be specified in either URLLC or coverage enhancement.   + If specified outside of the Cov Enh WI, then further PUCCH enhancements are not needed in Cov Enh * Multi-TRP support for dynamic PUCCH repetition can be added on top of a single TRP version specified in Cov Enh or URLLC. * Techniques specified in Cov Enh for PUSCH and Msg3 should be sufficient for RedCap coverage recovery.   **Overall, we think enhancement should be limited to uplink channels in this work item**, given the large amount of work that will come with these channels already and that downlink control channel coverage can be achieved at least with commercially common gNB transmit power levels. |
| Qualcomm | In general, DL coverage enhancements (coverage recovery) should be included in RedCap, while the UL coverage enhancements should be in the CovEnh WI. |

It seems that the discussion points in this sub-section are similar to those in 2.1. As a result, further discussion can be carried out under 2.1.

# 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