**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]). |

Proposals:

* TBD

## Justification

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

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

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

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

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

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

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

Questions:

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

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| **Company** | **Views** |
| Samsung | It is understood that current draft reflects the outcome of the study item. As the moderator noted, the need for a potential change in the justification text depends on the objectives. This can be discussed in the third/last phase of this email discussion once the objectives are being finalized. |
| Intel | We are in principle fine with the justification. This may need to be updated based on final conclusion of the detailed objectives.  |

Proposals:

* TBD

## Detailed Objectives

### Potential PUSCH Enhancements

Related RAN1 agreements/conclusion:

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

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

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

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

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

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

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

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

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

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

Questions:

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

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| **Company** | **Views** |
| Sierra Wireless | In general, agree. Some specific comments:We would like to make this change to this bullet:* + - Option 1: Increasing the maximum number of repetitions~~, e.g.,~~ up to 32.

Increasing repeats beyond 32 would move into the LPWA (NB-IOT/LTE-M) type coverage category which should be strictly avoided. Also, >32 repeats would significantly decrease spectral efficiency and adds no coverage for eMBB case where data rate is 100kbps. We would like to make these changes to this bullet: * + - ~~[~~Sub-PRB transmission with multi-slot aggregation~~, e.g. 6 tones~~ [RAN1, RAN4]~~]~~

We do not think it is appropriate or needed for RAN PL to give guidance on the number of sub-carriers- WGs will make that decision. Editorial: “mechanism” should be “mechanism(s)” throughout |
| Samsung | For PUSCH repetition type A, we support to specify Option 2.For TB processing over multi-slot PUSCH, both solutions in the two sub-bullets provide gains by transmitting over multiple slots. Sub-PRB solution has been shown providing gains for the VoIP use case. We suggest to specify both.The word “integer” is ambiguous. If the intention is to exclude a mini-slot, there is no need to add it because the description already clarifies that the processing is over multiple slots. * Specify mechanism to support TB processing over multi-slot PUSCH [RAN1, RAN4]
	+ TBS determined based on multiple slots and transmitted over multiple ~~integer~~ slots. [RAN1]
	+ ~~[~~Sub-PRB transmission with multi-slot aggregation, e.g. 6 tones [RAN1, RAN4]~~]~~

For joint channel estimation, we are fine with the current description. |
| Intel | We are generally fine with the recommendated scope for potential PUSCH enhancement, which is mostly based on the outcome of NR CovEnh SI.For sub-PRB transmission with multi-slot aggregation, we are open to discuss it but this may also depend on overall scope and time budget of NR CovEnh WI.  |
| Panasonic | Not to support sub-PRB in order to manage TU. To take the other recommendations is in-line with the RAN1 recommendations. |

Proposals:

* TBD

### Potential PUCCH Enhancements

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

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

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

Questions:

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

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| **Company** | **Views** |
| Sierra Wireless | No strong view but feel that only ONE mechanism should be chosen to fit in TU budget.  |
| Samsung | PUCCH was identified as a bottleneck channel for coverage and we support to specify mechanisms to enhance PUCCH coverage. The SI concluded with no recommendations due to different views on which solutions to adopt, not on the need for PUCCH enhancements. We support the second bullet on PUSCH-repetition-Type-B like PUCCH repetition for basically same reasons as for having PUSCH-repetition-Type-B. Repetitions for PUCCH are already possible and the introduction of optimizations similar to Rel-15/16 PUSCH repetitions (e.g., start symbol to be the same in each slot, single repetition per slot, etc.) improve resource utilization/latency/coverage with a limited impact to specifications and gNB/UE implementations. Also, Rel-17 MIMO agreed to have intra-slot PUCCH repetitions to different TRPs to improve coverage – it would not make sense to preclude single TRP. We support the third bullet on dynamic indication of PUCCH repetition as it improves resource utilization/coverage. It is useful to adjust the number of repetitions to the number of PUCCH symbols and UCI payloads as a transmission power cannot increase over the repetitions. This can be done by indicating the number of repetitions for a PUCCH transmission by the DCI format triggering the PUCCH transmission. We support the fourth sub-bullet as we also support it for PUSCH and expect the requirements to be practically same.In summary, * ~~[~~Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]~~]~~
* ~~[~~Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]~~]~~
* ~~[~~Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]~~]~~
 |
| Intel | We do not support “Specify DMRS-less PUCCH with UCI payload up to 11 bits”. As illustrated in our tdoc RP-202804, performance difference existing PUCCH format 3 and DMRS-less PUCCH scheme is negligible, for various UCI payload size from 3 to 11 bits, and for different performance metrics including BLER and ACK performance. Further, the impact at gNB reciver is substantial if DMRS-less PUCCH scheme. In our view, the need to consider DMRS-less PUCCH scheme for PUCCH coverage enhancement is not justified and we do not support it. PUSCH repetition type B like PUCCH repetition enhancement and dynamic indication of PUCCH repetition factor can be specified for PUCCH coverage enhancement. Whether this can be specified under eURLLC or CovEnh WI can be further decided based on overall scope and time budget. In our view, both schemes can help in improving the PUCCH coverage compared to existing PUCCH repetition mechanism. For instance, assuming special slot of 7 UL symbols and 14-symbol uplink slot, PUCCH repetition enhancement following PUSCH repetition type B can be employed to transmit 7-symbol long PUCCH with 3 repetitions, while existing PUCCH repetition scheme can only have 2 repetitions. Similar to PUSCH coverage enhancement, DMRS bundling across PUCCH repetitions should be considered as an objective for PUCCH coverage enhancement, which includes joint channel estimation and inter-slot frequency hopping with inter-slot bundling.  |
| Panasonic | "Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]" can be within URLLC."[Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]]" is quite similar to PUSCH and it should be within the scope.On "[Specify DMRS-less PUCCH with UCI payload up to 11 bits [RAN1, RAN4]]", some more discussion of the frequency and timing error would be required to satisfy the existing functionalities. On "[Specify mechanism to support PUSCH-repetition-Type-B like PUCCH repetition [RAN1]]", not to take it because of the lack of TU. |

Proposals:

* TBD

### Potential Enhancements for Other Channels

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

#### Potential Msg3 Enhancements

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

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

Questions:

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

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| **Company** | **Views** |
| Sierra Wireless | Recommend for inclusion in WI. Should not be large item and would be good for RedCAP UEs with 3dB antenna degradation. |
| Samsung | Msg3 PUSCH and PRACH were identified as bottleneck channels for coverage in some scenarios. Coverage enhancements are especially needed for FR2 as observed in the evaluation, and in real deployments as pointed out by various operators in SI discussions. Msg3 PUSCH cannot benefit of the beam refinement mechnisms available in connected mode, and relying on retransmissions for Msg3 PUSCH is inefficient. We recommend to specify mechanism to support PUSCH repetitions for Msg3. |
| Intel | We support to specify coverage enhancement for Msg3 PUSCH. As outcome of NR CovEnh SI, Msg3 PUSCH was identified as potential bottleneck channels at least for FR2. As captured in Table 5.2.2-1 in TR38.830, relative difference between Msg3 PUSCH and reference channel, i.e., PUCCH format 1 in Urban 28GHz with O2I is 3.4dB. In our view, Msg3 PUSCH needs to be enhanced in order to meet the target requirement. During NR CovEnh SI, Msg3 PUSCH with repetition was investigated extensively as solutions for coverage enhancement. So we support to specify mechanism to support PUSCH repetitions for Msg3. |
| Panasonic | Yes. Trying to have the common design with PUSCH enhancement as much as possible. |
|  |  |

Proposals:

* TBD

####  Potential PRACH Enhancements

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

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

Questions:

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

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| **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. |

Proposals:

* TBD

#### Any other channels?

Questions:

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

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| **Company** | **Views** |
| Intel | For NR CovEnh WI, we do not see the need to enhance any other channels.  |

Proposals:

* TBD

### Other Aspects

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

Related RAN1 agreements/conclusion:

***Conclusion:***

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

Reference RP-202211 has some detailed proposals.

Questions:

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

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| **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. |
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Proposals:

* TBD

#### Potential Interaction with NTN

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

Question:

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

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| **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. |

Proposals:

* TBD

#### Any other specific aspects?

Question:

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

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| **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.  |

Proposals:

* TBD

# Conclusion

Based on the email discussion, the following are proposed:

* TBD

# References

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

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

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

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

RP-202352 Views on Coverage Enhancement WI Intel Corporation

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

RP-202360 New WID on NR coverage enhancements China Telecom

RP-202410 Views on WI for NR coverage enhancement Ericsson

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

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

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

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

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

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

Shanghai Bell, China Telecom, SoftBank, Thales, Sharp

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

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

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

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

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

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

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