**3GPP TSG RAN WG1 Meeting #104-E R1-210zzzz**

**e-Meeting, January 25th – February 5th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Feature Lead Summary #1 for NR Positioning UL-AoA Enhancements**

**Agenda item: 8.5.2**

**Document for:** **Discussion and Decision**

Introduction

In this document, we provide summary of contributions [1]-[19]submitted for the AI 8.5.2 on enhancements for UL-AOA positioning method as a part of the Rel.17 NR Positioning Enhancements work item. In addition, we provide initial set of proposals for RAN WG1 discussions/decisions at the RAN1#104E meeting.

# Summary of Proposed Enhancements

In this section, we provide summary of the major topics that have been identified based on review of the submitted contributions:

* Reporting and measurements enhancements for UL-AOA NR Positioning
  + [OPPO, [1]], [Huawei, [2]], [ZTE, [3]], [CATT, [4]], [vivo, [5]], [Futurewei, [6]], [InterDigital, [11]], [Sony, [12]], [CMCC, [13]], [Qualcomm, [17]], [DOCOMO, [18]], [[Ericsson, [19]]](#_Toc61904130)
* Support of different antenna array configurations (e.g. ULA, different antenna spacing)
  + [Huawei, [2]], [vivo, [5]], [Futurewei, [6]], [Intel, [9]], [Ericsson, [19]]
* Calibration of gNB angle error and reference UE
  + [Huawei, [2]], [vivo, [5] - FFS], [CATT, [4], [BUPT,[7]]
* LOS/NLOS identification for UL-AOA measurements
  + [OPPO, [1]] (by implementation), [CATT, [4]], [Futurewei, [6]], [Intel, [9]]
* Assistance signaling for UL-AOA measurements (LMF assistance to gNB)
  + [CATT, [4]], [Nokia, [8]]
* SRS physical structure enhancements (sequence, RE mapping, multi-port SRS)
  + [LGE, [10]], [Fraunhofer, [14]]
* Power control enhancements of SRS for positioning
  + LGE, [10]], [Samsung, [15]]
* gNB/UE beamforming related aspects
  + [Nokia, [8]], [Samsung, [15]]
* SRS for positioning transmission priority
  + [InterDigital, [11]]
* Enhancements for UE timing advance
  + LGE, [10]]
* DL PRS-RSRP measurements enhancements
  + [Apple, [16]]

# Discussion on Proposed Enhancements

## Reporting and measurements enhancements

There are a lot of various proposals for gNB reporting and measurements enhancements as listed below:

* Study implementation based solution vs reporting of multiple AOA, associated UL-RTOA, associated SRS-RSRP [OPPO, [1]]
  + Motivation:
    - Improve the performance of UL AOA
* Per path UL AOA measurements/reporting [Huawei, [2]]
  + Motivation:
    - Positioning via reflections and spatial consistency checks
* Additional beam information reporting [ZTE, [3]] (e.g. antenna layout, beam width, beam vectors and corresponding gains etc.)
  + Motivation:
    - LMF can search for a right direction in an angle range, handling of sidelobes
* AOA & RTOA measurements associated to multi-paths to LMF for AOA positioning [CATT, [4]]
  + Motivation:
    - Discriminate AOA measurements corresponding to the LOS path from AOA measurements corresponding to the NLOS path
    - Use of advanced algorithms potentially to achieve a higher positioning accuracy
* Additional angle information of multiple paths [vivo, [5]] (RSRP, timing information per each angle)
  + Motivation:
    - Helps LMF to decide which angle is better for accurate positioning
* Detailed Tx/Rx beam information [Futurewei, [6]]
  + Motivation:
    - LMF to decide which angle is better for accurate positioning
* Reporting of UE orientation information from the UE [InterDigital, [11]
  + Motivation:
    - Network may be able to determine angle of transmission of SRSp depending on the UE orientation information and configured SRSp resource set and resource ID
* Uncertainty of the AOA and SRS Resource ID [Sony, [12]]
  + Motivation:
    - Helps to filter out some unreliable AOA measurements
    - Filter out undesired report from certain gNB
* Multiple UL AOA with associated ToA measurements [CMCC, [13]]
  + Motivation:
* Report multiple tuples (UL-AOA, UL-RSRP, RTOA/gNB Rx-Tx) within a single report [Qualcomm, [17]]
  + Motivation:
    - Helpful in advanced fusing algorithms
* Reporting multiple UL-AOAs w/ timing measurements [DOCOMO, [18]]
  + Motivation:
    - Single UL-AOA reporting may be insufficient to achieve a certain positioning accuracy for especially for NLOS
* Velocity of the UE should be reported to the network [Ericsson, [19]]
  + Motivation:
    - For estimation of AOA at TRPs

### Round – 1

**Proposal 1-1**

* NR supports combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements defined per channel path
  + FFS reporting details etc.

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| Company Name | Comments |
| CATT | Are we planning to introduce new “per channel path” definition of UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP measurements? If not, suggest make the following wording change “NR supports combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements per channel path” |
| Qualcomm | Support |
| Nokia/NSB | Two questions for clarification: 1) is the intention that these measurement combinations would be mandatory or optional for different positioning techniques? E.g., does UL-TDOA now require UL-RSRP and UL-AoA to be reported by TRP?  2) Is the decision to report on multiple channel paths left to the measuring TRP, similar to additional path reporting for RSTD? Or is it configured by LMF and required? |
| Fraunhofer | Do not support.  We do not see an improvement in terms of accuracy for the UL-AoA method by the above proposal. The additional reporting, depending on the “per channel definition”, is already supported in NRPPa. |
| ZTE | Not support. This proposal is unclear to us.   1. Is the combination means different positioning methods defined in Rel-16? In our understanding, this is already supported by implementation. 2. What does “per channel path” means? Is it similar to additional paths defined in Rel-16? |
| China Telecom | This proposal may need further clarified.  In our understanding, the motivation of this proposal is to provide more information of other beams or paths, so that the estimation of UL-AOA accuracy can be improved. What does the ‘combination’ and ‘per channel path’ mean is not clear for us, which may need be further clarified. |

## Support of different antenna array configurations

The following issues were raised for specific antenna configurations, e.g. Unilateral Linear Arrays (ULA):

* Ambiguity of angle measurements (e.g. due to different antenna spacings)
* Bias in angle measurements when gNB/TRP antenna array and UE are located at different heights

In order to address these issues, the following was proposed

* Firstly the use cases and scenarios for ULA antenna array should be discussed and confirmed [vivo, [5]]
* Reporting of multiple angle values per path or indication of the TRP antenna array orientation in the local coordinate system [Intel, [9]]
* Angle measurement defined with respect to the ULA antenna direction [Huawei, [2]]
* Enhanced AOA measurement with respect to the ULA antenna orientation [Futurewei, [6]]
* Reporting of the true AOA for ULA antenna configuration is supported by rel17 NR positioning enhancements [Ericsson, [19]]

### Round – 1

**Proposal 2-1**

* In case of UL-AOA measurements ambiguity,
  + gNB reports multiple values of UL-AOA measurements per path
* In case of ULA,
  + gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival
* FFS details

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| Company Name | Comments |
| CATT | We would like to understand a little more about this proposal.   1. “In case of UL-AOA measurements ambiguity,    1. gNB reports multiple values of UL-AOA measurements per path”   it is unclear to us what it means with the condition “in case of UL-AOA measurements ambiguity”, and it is also unclear to us why “gNB reports multiple values of UL-AOA measurements per path” assume the gNB receives a UL SRS resource from multipaths. For example, if gNB detects 4 paths when receives a UL SRS resource, does it means the gNB may report N UL-AOA measurements per path, i.e., total 4N UL-AOA measurements to LMF?   1. “gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival”. It is also unclear the intention of the proposal. gNB already support reporting UL-AOA measurement, which include both azimuth of angles of arrival. |
| Qualcomm | First bullet is related to Section 3.1.1: The framework in 3.1.1 can be general enough for a gNB to report multiple UL-AoAs, no need to discuss it separately in this proposal.  For the 2nd bullet, for ULA, the proposal focuses on a specific way of enhancing the ULA scenario. As it was noted in today’s GTW discussion, the identified problem could potentially be solved by having AoA reporting to be optional; (reference from Huawei/HiSilicon paper R1-2100237):    Our understanding of the problem that some companies identify is that, with a single ULA, it is more natural to think of the ULA axis as the z-axis in LCS and thus the measured phi-prime should be ZoA and not A(zimuth)oA -- whereas the signaling makes ZoA optional and AoA mandatory; or in other words, in the current NRPPa specification, a gNB might not be able to report an LCS & an AoA that is consistent with the measurement.  However, in this case, the network should define the LCS such that the z-axis is along the ULA direction, and then report only the ZoA relative to that z-axis (which based on our understanding, is the single angle that the network should report; aka it is not, strictly speaking a function of the azimuth and zenith angles as suggested in the proposal). The X and Y axes can be chosen in any manner (any 2 perpendicular lines in the plane perpendicular to the z-axis), and LCS-to-GCS mapping would be well defined.  If such a simple change in NRPPa specification does not solve the identified problem, then there needs to be additional technical discussion to understand better the issue that companies bring up for discussion. Could the supporters of a different solution clarify why the above solution would not address their concerns? |
| Nokia/NSB | We tend to agree with the comments from QC and would like to better understand the problem at hand. |
| ZTE | For the first bullet: agree with Qualcomm.  For the second bullet.:In our understanding, current spec supports AoA as mandatory but ZoA as optional. Therefore, if TRP is deployed with ULA, only AoA (azimuth) report is enough. In this case, the ULA axis should be regarded as x-axis in LCS. |
| China Telecom | We agree with Qualcomm’s comments. But we still confuse about what the second bullet’s intention, is it mean that in ULA case, both AOA and ZOA should be mandatory? |

## Calibration of gNB angle error and reference UE

The following options were proposed to support calibration of gNB angle error measurements:

* Introduce a calibration/reference UE [Huawei, [2]], [vivo, [5] - FFS], [CATT, [4]
  + Motivation:
    - Use known location to mitigate the gNB angle error
* Support LMF assisted angle calibration [Huawei, [2]]
  + Motivation:
    - Calibrating the phase/amplitude error across antenna elements
* Correction of the fixed phase deviation between channels of gNB antenna [BUPT,[7]]
  + Motivation:
    - Accurate UL AOA measurements

### Round – 1

**Proposal 3-1**

* Further study the following two alternatives for gNB/TRP antenna array calibration to facilitate accurate UL-AOA measurements:
  + Alt.1: NR supports reference UE with known coordinates/orientation for UL-AOA measurement calibration
  + Alt.2: Procedure for calibration of UL-AOA measurements is up to gNB/TRP implementation

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| Company Name | Comments |
| CATT | Support Alt.1 and suggest the following wording changes::   * NR supports using the information provided by a reference UE with known coordinates/orientation for UL-AOA measurement calibration * FFS: the details of the procedure and signaling |
| Qualcomm | We are supportive of Alt. 1 however, we don’t see the need of calling it a “reference UE”; it can be a gNB or some other device; these decisions can be discussed/finalized later, and there may need to have upper layer WGs included in the discussion. Suggest to change the first option by saying: “reference device or reference entity or reference node”.  Additional changes over the proposal from CATT:   * NR supports using the information provided by a reference ~~UE~~node with known coordinates/orientation for UL-AOA measurement calibration * FFS: the details of the procedure and signaling, whether the reference node can be a UE, a gNB, or another device |
| Nokia/NSB | In principle we are okay with Alt. 1 with update from CATT/QC. However, the general concept of reference UE is being discussed for multiple techniques and we think that we should not do a piecemeal solution but rather have a comprehensive agreement if possible. |
| Fraunhofer | Support Alt1. |
| ZTE | Prefer Alt.2. No spec change is needed. |
| China Telecom | Support Alt1 with update from CATT/QC. |

## LOS/NLOS identification for UL-AOA measurements

The following proposals were discussed for with respect to LOS/NLOS identification to improve accuracy of UL-AOA positioning.

* AOA measurements associated with LOS/NLOS identifier and a confidence level [CATT, [4]]
  + Motivation:
    - Accuracy of AOA positioning
* LOS indicators as soft values to the network or LMF [Futurewei, [6]]
  + Motivation:
    - To improve positioning accuracy using regularization techniques
* NLOS link rejection by polarization [Futurewei, [6]]
  + Motivation:
    - Improve accuracy, identify NLOS direction (relative changes in their polarization orientation)
* Indication of link propagation type (LOS/NLOS) and reliability metric [Intel, [9]]
  + Motivation:
    - Improved UL-AOA positioning accuracy

### Round – 1

**Proposal 4-1**

* gNB/TRP reports estimate of LOS/NLOS link type identification to facilitate accurate UL-AOA positioning
  + FFS details for LOS/NLOS link type identification and signaling

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| Company Name | Comments |
| CATT | Support and suggest the following wording changes:   * NR supports gNB/TRP to reports LOS/NLOS link type identification associated with UL-AOA measurements to facilitate accurate UL-AOA positioning   + FFS details for LOS/NLOS link type identification and signaling |
| Qualcomm | Not support. Sending a discretized AoA/RTOA/RSRP as proposed in Proposal 3.1 is a more generic way to solve this problem. Let everything else up to the LMF implementation, without having to ask the gNB to derive by-product metrics; send over to the positioning engine all the information. |
| Nokia/NSB | While we are supportive of LoS/NLoS identification, we don’t feel this should be discussed during this meeting and should wait for any potential update to the WID given the discussions at RAN. |
| Fraunhofer | Do not support.  LOS/NLOS identification or mitigation is not part of the current WID objectives. |
| ZTE | Agree with Nokia. This can be discussed when NLOS/multipath mitigation is in WID. |
| China Telecom | We support the proposal 4-1. Even though the NLOS/multipath mitigation is not included in current WID, it does help improve the UL-AOA positioning accuracy and can regard as kind of procedure and measurements. We are also OK to discuss this when the WID is updated. |

## Assistance signaling for UL-AOA measurements

The following options were proposed to assist UL-AOA measurements:

* Indication of expected AOA parameters [Nokia, [8]]
  + Motivation: Assist non-serving cell TRPs in UL-AOA measurements
* Indication of estimated UE position and the uncertainty [CATT, [4]]
  + Motivation: Aid the UE/gNB in the reception of the DL/UL reference signals and providing reliable NR timing and angular (especially AOA) measurements

### Round – 1

**Proposal 5-1**

* NR supports assistance signaling from LMF to gNB/TRP to facilitate UL-AOA measurements
  + FFS details of LMF assistance signaling

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| Company Name | Comments |
| CATT | Support. |
| Qualcomm | Support |
| Nokia/NSB | Support. Suggest the following small changes:   * NR supports enhanced assistance signaling from LMF to gNB/TRP to facilitate improved UL-AOA measurements |
| Fraunhofer | Do not support.  It is not clear what improvements are achieved if the proposal is supported. |
| ZTE | Generally fine with the proposal and leave details to next meeting. |
| China Telecom | Support. |

## SRS physical structure enhancements

The following options were proposed to enhance SRS physical structure:

* Long ZC sequence (Length = existing sequence length \* comb size) [LGE, [10]]
  + Motivation:
    - More cyclic shifts and root indexes can be used => cross-correlation can be improved
* Enhanced SRS sequence mapping rule [LGE, [10]]
  + Motivation:
    - Adjustment of phase are not necessary
* Multi-port SRS for positioning [Fraunhofer, [14]]
  + Motivation:
    - Reduced time-frequency resource overhead. TRP may take advantage of the multipath components received from multiple SRS resources coherently transmitted

### Round – 1

The proposed above enhancement seems to be a general one i.e. applicable to all UL NR positioning measurements.

**Proposal 6-1**

* FFS physical structure enhancements of SRS for positioning

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| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement of “SRS for positioning” was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We need to provide an update for this WI in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting? |
| Nokia/NSB | Do not support. |
| Fraunhofer | The WID objective mentions: “Specify the procedure, measurements, reporting, and signalling for improving the accuracy of UL AoA…”  Multi-port SRS transmission has a direct impact on the UL-AoA accuracy especially for multi-TRP scenarios. A TRP can measure the SRS from the multiple ports of the same UE and coherently process the measurements so that a better AoA estimate corresponding to the first arrival is achieved.  In fact this in our view, this is one of the few proposals for UL-AoA improvements from RAN1 perspective. |
| ZTE | Not support.  SRS enhancements were discussed during SI phase, no consensus was reached. |
| China Telecom | We think this should not be discussed according to the current WID scope, but we are fine with the SRS physical structure enhancements. |

## Power control enhancements of SRS for positioning

The following open-loop power control enhancements were proposed

* Multiple DL RS resources as path-loss reference to each SRS resource set. [LGE, [10]]
* Association between the multiple path-loss reference RSs and SRS resource within a SRS resource set. [LGE, [10]]
  + Motivation:
    - Improve reception at neighbour gNBs/TRPs
* Power control enhancements [Samsung, [15]]
  + Motivation:
    - Reliable reception at neighbour TRPs/gNBs that are far from UE

### Round – 1

The proposed above enhancements seem to be general ones, i.e. applicable to all UL NR positioning measurements.

**Proposal 7-1**

* FFS association of pathloss reference RSs and SRS resources for positioning within an SRS resource set
* FFS power control enhancements for SRS for positioning

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| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We may need to provide an update for this WI in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting? |
| Nokia/NSB | We also brought some power control proposals in our TDoc under “Others” – R1-2100551. We are open to discussing. While we are supportive of enhancing power control in Rel-17 we also acknowledge the comments above about WI scope. |
| ZTE | It’s out of WID scope. |
| China Telecom | We think this should not be discussed according to the current WID scope, but we are fine with the power control enhancements. |

## gNB/UE beamforming related aspects

The following beamforming related techniques were proposed for study to improve UL-AOA performance:

* Differential beamforming technique for UL-AOA positioning method [Samsung, [15]]
  + Motivation:
    - Accuracy enhancements, latency reduction, overhead reduction
* Beam interpolation based AOA estimation [Nokia, [8]]
  + Motivation:
    - Accurate measurement of UL-RSRP

### Round – 1

**Proposal 8-1**

* Further study performance of differential beamforming and beam interpolation-based AOA estimation for UL-AOA positioning and particular design aspects for specification work

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| Company Name | Comments |
| CATT | Support further discussion. The investigation may not be not limited to “performance” only. |
| Qualcomm | We may need to provide an update in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting?  Its unclear what is the spec impact that we are going after with this proposal. Can it be clarified further what is the spec support needed? |
| Nokia/NSB | Support. |
| ZTE | It’s unclear what spec changes are expected. |
| China Telecom | We support the proposal, and the spec impact also needs to be considered besides the performance. |

## SRS for positioning transmission priority

The SRS for positioning prioritization was discussed:

* Prioritization of SRS for positioning with respect to other signals and channels [InterDigital, [11]]
  + Motivation:
    - SRS for positioning transmission may be dropped when the UE has another data for UL transmission => degradation of low latency positioning services

### Round – 1

The proposed above enhancement seems to be a general one i.e. applicable to all UL NR positioning measurements.

**Proposal 9-1**

* Further study prioritization of SRS for positioning with respect to other signals and channels

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| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | SRS prioritization would be related to all UL and DL/UL methods: UL-AoA, UL-TDOA, MRTT; it will not help the AoA method only. We are supportive to be discussed, but it should be understood that it related to all UL measurements. |
| Nokia/NSB | Agree with above comments. |
| Fraunhofer | Share the view of CATT. |
| ZTE | Agree with CATT. |
| China Telecom | Agree with CATT. |

## Enhancements for UE timing advance

The following enhancements were proposed with respect to the SRS for positioning transmission timing:

* SRS resource-specific TA configuration [LGE, [10]]
  + Motivation:
    - For transmission intended to a neighbour cell, TA of the SRS resource should also be intended to the target neighbour cell.

### Round – 1

The proposed enhancements were discussed in Rel.16 and there was no consensus to introduce such functionality for NR SRS for positioning.

**Proposal 10-1**

* FFS support of SRS resource-specific TA configuration

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| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We don’t see the technical need to reopen this issue. Benefits have been unclear, especially if we are talking about InH/inF scenarios where the distances are small. |
| Nokia/NSB | As this would not improve the accuracy we don’t think this is in the scope of the WI. |
| ZTE | It’s out of WID scope. |
| China Telecom | Agree with CATT. |

## DL PRS-RSRP measurements enhancements

* Association of DL-PRS-RSRP measurements with a time window, determined by UE [Apple, [16]]
  + Motivation:
    - PRS for DL-AoD, is not tied with the first detected path in time. Report may be often biased toward the NLOS path
  + NOTE: Proposal relates to DL-AoD enhancement and thus should be covered under another AI 8.5.3

### Round – 1

**Proposal 11-1**

* Discuss proposal under AI 8.5.3 unless the same approach is suggested for UL-AOA by proponent

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| Company Name | Comments |
| Qualcomm | The proposal above seems to be Dl-AoD, unless there was a typo. |
| Nokia/NSB | Agree with FL view. Seems that Apple may have flipped their DL-AoD and UL-AoA Tdocs. |
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Conclusions

In this contribution, we have provided review of the submitted contributions for NR Positioning UL-AOA enhancements and prepared initial set of proposals to facilitate further discussion/decision.

References

1. R1-2100129 Enhancements for UL AOA Positioning OPPO
2. R1-2100237 Enhancement for UL AOA positioning Huawei, HiSilicon
3. R1-2100294 Accuracy improvement for UL-AOA positioning solutions ZTE
4. R1-2100386 Discussion on accuracy improvements for UL-AOA positioning solutions CATT
5. R1-2100446 Discussion on potential enhancements for UL-AOA method vivo
6. R1-2100488 Discussion on improving the accuracy of UL AOA positioning solutions FUTUREWEI
7. R1-2100497 Accuracy improvements for UL-AOA positioning solutions BUPT
8. R1-2100549 Initial views on enhancing UL AOA Nokia, Nokia Shanghai Bell
9. R1-2100658 NR positioning enhancements for UL-AOA method Intel Corporation
10. R1-2100709 Discussion on accuracy improvement for UL-AOA positioning LG Electronics
11. R1-2100753 Discussions on techniques to improve accuracy for UL-AOA positioning solutions InterDigital, Inc.
12. R1-2100863 Discussion on accuracy improvements for UL-AOA positioning method Sony
13. R1-2101047 Discussion on UL-AOA enhancement CMCC
14. R1-2101132 UL-AOA positioning enhancements Fraunhofer IIS, Fraunhofer HHI
15. R1-2101211 Discussion on accuracy improvements for UL-AOA positioning solutions Samsung
16. R1-2101388 Accuracy enhancements for DL-AoD positioning technique Apple
17. R1-2101469 Potential Enhancements on UL-AOA positioning Qualcomm Incorporated
18. R1-2101617 Discussion on UL-AOA positioning enhancements NTT DOCOMO, INC.
19. R1-2101755 Enhancements of UL-AOA positioning solutions Ericsson