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3GPP TSG-RAN WG1 Meeting #103-e R1- 21NNNN

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

Agenda Item: 8.5.3

Source: Moderator (Ericsson)

Title: FL summary for AI 8.5.3 Accuracy improvements for DL-AoD positioning solutions

Document for: Discussion, Decision

1. Introduction

This FL summary documents the proposals and discussions for agenda item 8.5.3, based on the following chairman decision:

[104-e-NR-ePos-03] Email discussion/approval on accuracy improvements for DL-AoD positioning solutions with checkpoints for agreements on Jan-28, Feb-02, Feb-05 – Florent (Ericsson)

The FL proposals are based on submission to AI 8.5.3 [1-21], but also including [16] and [21] which where submitted to AI 8.5.2 but contained proposals relevant to 8.5.3.

The proposals in the contributions centered on the following aspects:

Enhancements to UE reporting (LPP)

* Aspect #1 reporting of first path RSRP
* Aspect #2 support of NLOS identification
* Aspect #3 Adjacent beam reporting
* Aspect #4 Rx Beam reporting enhancements
* Aspect #5 CIR reporting for AoD
* Aspect #6 extension of number of reported RSRP measurements
* Aspect #7 Signalling to assist reference UE calibration

Enhancements to gnodeB signalling (NRPPa)

* Aspect #8 beam orientation error handling
* Aspect #9 gNodeB beam Shape information signalling
* Aspect #10 gnodeB based calculation of AOD
* Aspects #11 TRP antenna Array configuration signalling
1. Aspects for discussion

## UE Reporting aspects:

### Aspect #1 reporting of first path RSRP

#### Summary and FL proposal

Most companies support introducing an RSRP measurement of the earliest received path RSRP for a PRS resource configured for DL AoD, with some companies going further and support reporting more than one path, or the time difference between the first path received at each TRP [1][2][3] [7] [10][11][12][13][14][15][16][18][19][20]. The following proposals were submitted:

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | Proposal 3: The UE uses the LOS path of one DL PRS resource to measure the RSRP measurement report for DL-AoD. Proposal 4: In DL-AoD measurement report, besides the RSRP measurement of DL PRS resources for each TRP, the UE also reports the relative time-of-arrival of those reported DL PRS resources of each TRP. |
| [2] | ***Proposal 2: Support path specific power reporting for DL-AoD positioning.*** |
| [3] | ***Proposal 1:*** *In addition to RSRP measurement, Rel-17 UE should have capability to support timing measurement for DL-AOD positioning method and report the timing information for network based positioning.* |
| [6] | ***Proposal 4***: Additional measurement with angle information relative to the first detected path should be further studied including its feasibility to improve AoD based positioning methods. |
| [7] | **Proposal 2**: Support timing based measurement and report for improving positioning accuracy of DL-AoD.  |
| [10] | **Proposal 1: Introduce first path coefficient (Hfp) (i.e the amplitude of the first path in the received signal's power delay profile) in DL-AoD measurement report from UE to LS.** |
| [11] | **Proposal 1: Support the enhancement of reporting PRS-RSRP associated with ToA of the first arrival path.** |
| [12] | *Proposal 1: Report DL TDoA together with DL PRS-RSRP for DL AoD.* *Proposal 2: To indicate the first arrival path by reporting the arrival time of each beam in beam measurement report.* |
| [13] | **Proposal 2: To improve the DL-AoD accuracy in UE-assisted mode, support enhanced UE measurements and reporting by considering the following:** * **Reporting additional correlation information (ex. CIR reporting)**
* **Reporting of the estimated first arriving path, multipath and noise power**
* **Reporting of timing measurements on the DL-PRS resources along with the RSRP report.**
 |
| [14] | **Proposal 2-3**: The RSRP measurement may support the single path RSRP measurement. Therefore, new RSRP measurement definition could be needed |
| [15] | ***Proposal 1: For DL-AoD positioning method, UE can report the RSRP measurement for first arrival path together with a LOS/NLOS indicator.***  |
| [16] | **Proposal 1:** Support in Rel-17 that DL-PRS-RSRP calculation for each beam is associated to a time window in which the RSRP measurement is performed.  |
| [18]. | ***Proposal 2: Support UE reporting of RSRP side information and additional measurements to improve the accuracy of the DL-AoD estimate, especially in NLOS scenarios. FFS details such as type of side information and timing measurements, aperiodic/periodic measurement windows, etc.*** |
| [19]  | **Observation 1:** * **Rel-17 can consider using other information (e.g. arrival path timings) in addition to RSRP for UE assisted DL-AoD positioning.**
 |
| [20] | **Proposal 1 Define a DL PRS peak-RSRP measurement for the power of a specific peak in the channel impulse response of a received DL-PRS resource.****Proposal 2 Include the DL PRS peak-RSRP in the NR DL-AoD Location Information alongside the existing DL PRS RSRP measurement.****Proposal 4 Include the DL PRS peak-RSRP in the NR DL-TDOA and multi RTT Location Information alongside the existing DL PRS RSTD measurement.****Proposal 5 The UE shall report the DL PRS Peak-RSRP and the corresponding DL PRS resource ID for each additional path in the RSTD and UE Rx-Tx time difference measurements.****Proposal 6 The UE shall report the strongest detected paths as additional paths (i.e. in addition to the first path).** |

Based on the set of proposals, it is proposed to have an initial agreement to support first-path RSRP measurement and reporting, while keeping open the additional details.

1. Support the DL-AOD enhancement of measuring and reporting PRS-RSRP based on first arriving path
	* FFS: Indication of the path arrival time
	* FFS: reporting of additional path to the first path.
	* FFS: Measurement definition
	* FFS: other method to support PRS-RSRP per path among OTDOA, UL TDOA

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | Support. We think that, Rel-16 AoD is to define multiple RSRP measurements to determine the direction between a TRP and a UE, and multiple directions are used to determine the UE location. Rel-17 AoD enhancement may still follow this method. We also understand that there are new proposals for AOD, such as using bluetooth’s solution. But we think it should be studied further, especially under NLOS. So we tend to focus on enhancing RSRP measurement methods in Rel-17 |
| vivo | In general, we are open to introduce the first path-RSRP, however, from our evaluation, the first path-RSRP cannot improve the performance significantly. We support it after the performance benefit and the use case is clear. So, we propose **Evaluate the performance benefit for DL-AOD enhancement with reporting PRS-RSRP based on the first arriving path first, if the benefit is clear, support it.** |
| Huawei/HiSilicon | Support in general, but to our understanding, the power of the path should no longer be called RSRP. |
| CMCC | Support |
| ZTE | Suggest revising the proposal to be more general. Meanwhile, remove last FFS since this AI only discusses DL-AOD.1. Support the DL-AOD enhancement of measuring and reporting ~~PRS-RSRP based on~~ the information of first arriving path,
	* FFS: power/amplitude based on the first arriving path
	* FFS: Indication of the path arrival time
	* FFS: reporting of additional path to the first path.
	* FFS: Measurement definition
	* ~~FFS: other method to support PRS-RSRP per path among OTDOA, UL TDOA~~
 |
| Nokia/NSB | We are generally okay with the updated proposal from ZTE. We are supportive of including time measurements (i.e., configuring RSTD between DL PRS of same TRP) along with the current DL-AoD measurement procedure. In that way we think this could be viewed as a bit separate proposal than “first path”.  |
| CATT | We have some concerns on this proposal. If the first arriving path is not the LOS path, the RSRP related to the first arriving path is still not the accurate RSRP for DL-AoD calculation. |
| Intel  | Support.  |
| InterDigital | We support the FL’s proposal |
| Lenovo, Motorola Mobility  | Open to Support, although we also share CATT’s concern on the main bullet regarding the RSRP accuracy if the first detected path is NLOS. |
| Qualcomm | It is the first meeting of the WI, and in some sense, since there may need to be an update of the WID, it is a soft continuation of the SI on the topic of Angle measurements. Therefore, we need to consider this in a more holistic approach. What we are trying to enable is the UE measuring and deriving measurements related to the first arrival path. This should be true for both UE-B and UE-A DL-AoD methods, and focusing only on reporting enhancements would not be enough. The necessary enhancements need to be in place so that the measurements are useful and the reporting is relevant (reporting enhancements just for the sake of reporting enhancements should be avoided). Having said the above, we prefer ZTE’s approach to keep the discussion more general and use the word “information”, since it can be, power, amplitude, angle measurements that a UE can report. We make the following adjustments on top of ZTE’s version: For DL-AoD, support enhancements, for both UE-based and UE-assisted, enabling measuring and, for UE-assisted, reporting ~~PRS-RSRP based on~~ ~~the~~ information related to the ~~of~~ first arriving path, FFS: additional assistance data to support these enhancementsFFS: power/amplitude/angle based on the first arriving pathFFS: Indication of the path arrival timeFFS: reporting of additional path to the first path.FFS: Measurement definition  |
| Apple | Support the intention |
| Ericsson | Support the proposal. Regarding Qualcomm and ZTE’s proposal, we prefer keeping the proposal focused on defining a new measurement for received power per path. There are many companies supporting to introduce this type of measurement, while few support measuring/reporting complex-valued channel measurement.  |
| DOCOMO | Support |

### Aspect #2 support of NLOS identification

#### Summary and FL proposal

The support of a LOS/NLOS detection/indication was brought up in [6][4][8][15][21].

|  |  |
| --- | --- |
| Source | Proposal |
|  [4] |  Proposal 1: RSRP measurements can be associated with a LOS/NLOS identifier for supporting DL AOD positioning. |
| [6]  | ***Proposal 1***: For the purpose of improving accuracy, methods to identify NLOS direction and the corresponding mitigation methods for DL-AoD measurements should be supported including the usage of transmissions and measurements of PRS signals with relative changes in their polarization orientation. ***Proposal 2***: Consider reporting additional CIR measurements back to the network for improving NLOS detection and positioning accuracy.***Proposal 3***: To improve positioning accuracy by regularization techniques the UE should report LOS indicators as soft values for each link for UE-assisted positioning. |
| [8] | ***Proposal 3:**** For the purpose of accuracy improvements, support enhancements so that the LMF knows a LoS direction of a TRP’s transmission beam to the UE.
 |
| [15] | ***Proposal 1: For DL-AoD positioning method, UE can report the RSRP measurement for first arrival path together with a LOS/NLOS indicator.***  |
| [21] | Proposal #3:● Support signaling indicating the LOS/NLOS link propagation type for DL-AOD positioning● Support signaling of reliability metric (with probability meaning) for NLOS detection (variable u in the range from 0 to 1, with absolute value showing reliability of decision) |

Since there is a variety of way to indicate LOS/NLOS on the proposals, we propose to agree on the principle of reporting LOS/NLOS information, and leave the details such as granularity (e.g. if the report is a binary indicator or a soft metric) to a future agreement.

1. For DL-AoD positioning method, UE can associate a measurement on a PRS resource with a report of LOS/NLOS state for the measurement
	* FFS: granularity of the state (binary indicator or soft metric)

####  First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | If UE can measure first path RSRP, we don't think the need to report LOS/NLOS state  |
| vivo | We prefer to discuss LOS/NLOS together with all methods (e.g. LOS/NLOS in angle-based method, LOS/NLOS timing-based method). So we propose to discuss it along with the discussion of LOS/NLOS identification in WID. |
| CMCC | We share similar views as MTK, in case that LOS link exists in the scenario, the solution proposed by Proposal 1 also helps the LMF decide the LOS beam direction. On the other hand, as we commented in AI 8.5.2, LOS/NLOS identification related issue is not included in the WID yet, we could postpone this discussion in the next meeting. |
| ZTE | This can be discussed in next meeting when LOS/multipath mitigation is in WID. |
| Nokia/NSB | Agree with above. Should wait to discuss based on potential WID update.  |
| CATT | Support. The LOS/NLOS identification is important for the accuracy improvement of DL-AoD positioning method. |
| Intel  | We are supportive of this proposal.We are OK to consider it later based on the WID revision.To MTK: the RSRP measurement may be not the best metric to identify the LOS/NLOS state. More acucrate approach is to use a channel impulse response realization and not the RSRP measurements.  |
| Lenovo, Motorola Mobility  | Support the FL’s proposal in principle to support a LOS/NLOS reporting mechanism for DL-AoD RSRP measurements to the network (at least for UE-assisted positioning). The extension to other positioning measurements and details could be handled as an FFS in conjunction with the previous RAN1 agreements relating to NLOS/multipath identification.  |
| Qualcomm | Similar view with CMCC |
| Apple | LOS detection is out of current scope. We share similar view as MTK/CMCC…  |
| Ericsson | We also think the LOS indication is currently out of scope.  |
| DOCOMO | Agree with CMCC. |

### Aspect #3 adjacent beam reporting

#### Summary and FL proposal

To enhance the granularity of AOD estimation, several contributions proposed to report adjacent beams in addition to the “best beam”[1][5][8].

|  |  |
| --- | --- |
| Source | Proposal |
| [1]  | Proposal 2: In DL-AoD UE measurement reporting, support the UE to report the RSRP of a few DL PRS resources carrying adjacent Tx beam directions.  |
| [5] | * ***Report up to 8 DL PRS-RSRP including the strongest PRS resource and adjacent PRS resources.***

Proposal 4: • To balance the accuracy and robustness, AoD enhancement by adjacent DL PRS-RSRP and limited beam information (the intersection point of multiple beams) need to be considered. |
| [8]. | ***Proposal 2:**** Need discussions on how to utilize the reception beam index for the accuracy improvements of DL-AoD based positioning, such as finding UE’s location when the UE is located between the transmission beams.

***Proposal 5:**** Consider enhancements for the accurate UE’s location estimation when the UE is located in between two different transmission beams.
 |

1. For DL-AoD positioning method, UE can associate a measurement on a PRS resource with an additional, adjacent PRS resources measurement
	* FFS: how to define / identify adjacent beams
	* FFS: required signaling to support use of adjacent beams

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | In 37.355, we can see that,NR-DL-AoD-MeasElement-r16 ::= SEQUENCE { dl-PRS-ID-r16 INTEGER (0..255), nr-PhysCellID-r16 NR-PhysCellID-r16 OPTIONAL, nr-CellGlobalID-r16 NCGI-r15 OPTIONAL, nr-ARFCN-r16 ARFCN-ValueNR-r15 OPTIONAL, nr-DL-PRS-ResourceID-r16 NR-DL-PRS-ResourceID-r16 OPTIONAL, nr-DL-PRS-ResourceSetID-r16 NR-DL-PRS-ResourceSetID-r16 OPTIONAL, nr-TimeStamp-r16 NR-TimeStamp-r16, nr-DL-PRS-RSRP-Result-r16 INTEGER (0..126), nr-DL-PRS-RxBeamIndex-r16 INTEGER (1..8) OPTIONAL, -- Cond SameRx nr-DL-AoD-AdditionalMeasurements-r16 NR-DL-AoD-AdditionalMeasurements-r16 OPTIONAL, ...}NR-DL-AoD-AdditionalMeasurements-r16 ::= SEQUENCE (SIZE (1..7)) OF NR-DL-AoD-AdditionalMeasurementElement-r16NR-DL-AoD-AdditionalMeasurementElement-r16 ::= SEQUENCE { nr-DL-PRS-ResourceID-r16 NR-DL-PRS-ResourceID-r16 OPTIONAL, nr-DL-PRS-ResourceSetID-r16 NR-DL-PRS-ResourceSetID-r16 OPTIONAL, nr-TimeStamp-r16 NR-TimeStamp-r16, nr-DL-PRS-RSRP-ResultDiff-r16 INTEGER (0..30), nr-DL-PRS-RxBeamIndex-r16 INTEGER (1..8) OPTIONAL, -- Cond SameRx ...}1, So we think the current spec structure already supports UE to report differential RSRP from the beams which are adjacent to the strongest beam.2, what can be further clarified is, whether the beams with incremental PRS-resourceID value are adjacent |
| vivo | Support.From our evaluation, the performance benefit of this enhancement is clear, so we agree with that.For question 1 of MTK, as my understanding, the spec only supports reporting multiple RSRP of different PRS resource, we can not guarantee to contain the RSRP corresponding to the strongest Tx beam and adjacent Tx beams. |
| Huawei/HiSilicon | We do not think it is practical to define or identify adjacent beams. |
| CMCC | We are open to discuss it. It seems that the proposal can provide benefits in accuracy; however, we are curious about how to identify adjacent beams.  |
| ZTE | Not support. This can be realized by implementation. In our understanding, if one beam is detected with highest RSRP, so adjacent beams will normally be received with high RSRP. In current specification, UE supports up to 8 RSRP per TRP, so it’s possible UE will report those beams including central beam and adjacent beams. |
| Nokia/NSB | We are open to potentially discuss further but would like the proponents to clarify the specification impact as we tend to agree with the above comments.  |
| CATT | We prefer not to define adjacent beams and related signaling. |
| Intel | Do not support. We do not see what will be additionally defined in the specification.  |
| Lenovo, Motorola Mobility | Support. Details on how to define/identify the reporting of RSRP measurements based on such a co-located group of adjacent beams and corresponding signalling aspects can be FFS. |
| Qualcomm | The UE can already report up to 8 RSRPs, each one with a different beam index. In other words, the UE already, in one report can add up to 8 PRS resources, these might or might not be adjacent; but this is up to UE implementation. Likely, beams that are pointing to a complete different direction than where the UE is located, would result in very low RSRP (i.e. bad measurement), and the UE would not report those measurements. Note that the UE in UE-based AoD, already knows which beams are next to each other, since it gets the assistance data that contains the boresight directions of each PRS resource, so if indeed it makes sense to report RSRP on adjacent beams, it can do this already in Rel-16. If the concern is that this information is not available in UE-assisted, then we can discuss sending this assistance data also for UE-A DL-AoD. In other words, this enhancement is an assistance data enhancement rather than a reporting enhancement. To continue on how the UE-A RSRP-based AoD is supposed to work, the UE reports the RSRP vector and then the LMF (assuming that it has the beam pattern information) it compares the RSRP vector vs. the expected RSRP vector (some people call it fingerprinting, others vector matching, pattern matching, etc, etc). In this procedure, it is up to the UE to pick PRS resources to be reported, and indeed, if the UE has the knowledge of which beams are adjacent, it could help the UE to have a good report. However, in this case, it is a gNB-to-the-UE-signaling enhancement. |
| Apple | The benefit of such an “association report” is not clear. Given that PRS-RSPR reports are associated to PRSs, and LMF knows the beams next to other beams, report from UE brings no more benefit.  |
| Ericsson | In the current state of the specifications, the LMF knows how the beams are organize and can derive the adjacent beams. However, the UE may chose to instead report a selection the strongest beams which may not be adjacent. Therefore we support the proposal.  |

### Aspect #4 Rx Beam reporting enhancements

#### Summary and FL proposal

In [9], it was proposed to associate a Tx and Rx beam pair of indices with the RSRP report, indicating the beam pair resulting in the strongest RSRP. In [11], it is proposed to report the Rx beam information to the LMF. [3] proposed to enhance the report by providing detailed Rx beam information including antenna virtualisation and beam direction. In [7] it was proposed to enhance the report by informing the LMF of the Rx beams relative angular difference.

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| --- | --- |
| Source | Proposal |
| [9]  | **Proposal 4: Introduce an indicator associated with a PRS resource/resource set or RX beam index to indicate TX beam or RX beam corresponding to the highest RSRP measurement.** |
| [11] | **Proposal 2: Support the enhancement of reporting the UE Rx beam information to the LMF. FFS the details of what/how to report the Rx beam information.** |
| [3] | ***Proposal 2:*** *Rel-17 NR positioning should support detailed Rx beam information, in which UE can provide its antenna virtualization and reception beam direction information.* |
| [7] | **Proposal 3*:*** Study angle difference measurements for AoA of DL PRS resources in Rel-17. |
| [8] | Proposal 1* A further restriction would be required so that the UE uses a reception beam to avoid worst case of the reception beam selection, even if the UE can ignore QCL type-D configuration of the PRS resources to use a fixed reception beam for DL-AoD technique.

***Proposal 2:**** Need discussions on how to utilize the reception beam index for the accuracy improvements of DL-AoD based positioning, such as finding UE’s location when the UE is located between the transmission beams.
 |
|  |  |

1. For AOD, the UE may optionally indicate the following Rx beam information

 A) An indicator that the reported resource gives the highest RSRP measurement

 B) Rx beam direction information

 C) Antenna virtualization for the Rx beam

 D) angular difference between Rx beams when using different Rx beams.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | 1, we think, finding the direction between a TRP and a UE lies in using a vector in which the elements are the differential RSRP between beams. Each vector stands for a direction implicitly. 2, so the key should be UE to fix the RX beam, so that the measured differential RSRP correspond to the beam response with each beam having its own pointing direction. It is less significant to consider using which RX beam |
| vivo | In general, we are okay with the main bullet. But for the sub-bullet, we have some questions and hope the proponents can clarify them.For A), as RSRP value has been reported, why we need an indicator for the highest PRSP.For B) and D), we think it may beneficial for positioning, but how the UE obtains the Rx beam direction information or angular difference needs to be explained clearly.For C) we support it if Antenna virtualization for the Rx beam is the Rx Beam index. |
| Huawei/HiSilicon | We do not think the proposal has any convergence. In general, we are OK to support UE panel reporting for associated RSRP or any enhancement of measurements for DL-AoD, similar to the method for mitigating UE Rx/Tx timing error. |
| CMCC | Support. The DL-AoD performance gain relies on both the Tx beam and Rx beam, especially for FR2. The best result would be obtained by the alignment of Tx and Rx beams. Therefore, it is beneficial to provide UE Rx beam information to the LMF, the details can be further discussed.  |
| ZTE | Support the main bullet. Details can be discussed in next meeting since we need to update WID in next RAN plenary. |
| Nokia/NSB | We are okay with the ZTE proposal of agreeing main bullet but some of the proposals are quite different. We do not see what the motivation for A) is. For B) wouldn’t this require that the UE is aware of its orientation for it to be useful? For C) more details from the proponents would be helpful. D) We support it. To respond to vivo: we think that the angle difference between the RX beams could be the measured by the UE by assuming that the direction of the beam with the highest power (i.e., similar to AoD for DL side) and then taking the difference between such angles of 2 RX beams.  |
| CATT | We prefer this proposal as low priority in this meeting. |
| Intel | Do not support. The UE orientation in space is not known/calibrated, so any change in the UE orientation causes changes in the RX beam direction information.  |
| InterDigital | We support the proposal. We are supportive of B). Our view is that sudden change in UE orientation will deteriorate AoD measurements. Therefore, UE orientation information (proposal captured in 2.3.4) will be helpful for the LMF to determine the UE position based on the measurements. The UE rotation information may be obtained by implementation. Details can be discussed in future meetings. Option A) may have came from [9]. One of the use cases is to indicate that without reporting RSRP, include an indicator for in the measurement report that the corresponding PRS beam yields the highest RSRP. For example, such operation may be useful to judge which way the UE is facing without asking for excessive amount of measurement reports. The indicator can be obtained by comparing multiple groups of averaged RSRPs across PRS resources. |
| Lenovo, Motorola Mobility | Generally, support the intention of the main bullet proposal. The overall aim of the candidate information solutions B, C), D) is to improve the DL-AoD performance in NLOS scenarios. For C) this might depend on UE’s capability, while for D) the details for computing the DL-AoA need to be decided upon (also related to Aspect#8 of FL’s summary). For A) , wondering if the LMF can already derive this based on the reported RSRP values.  |
| Qualcomm | It is unclear to us how this information will be used, or whether we are in that level of optimization of this procedure that such detailed Rx beam information is needed to do a good DL-AoD method. RSRP-based DL-AoD is about the angle at the gNB, and what is needed is the UE’s measurements to not be affected by other factors (e.g. changing Rx beam) and a way to map the RSRP-report to an Angle. The aspects that these proposal treat seem secondary to us.  |
| Apple | We do not support this proposal. Basically it is not clear how the UE’s Rx beam information at LMF would be useful, given that UE’s orientation may change.  |
| Ericsson | For A) We think that the discussion on rx beam delay group / panel identification in agenda 8.5.1 will probably yield a solution also for AoD. Therefore we could probably skip the discussion in this agenda item regarding Rx beams. B) we have a similar concern from other companies regarding how to maintain UE orientation C) how the LMF will use this is unclear.D) support the principle. However, the beams where the two measurements are performed should be in the same panel/delay group to provide a meaningful result.  |

### Aspect #5 CIR reporting for AoD

#### Summary and FL proposal

In [21] it was proposed to support reporting the complex channel coeffient per path for DL-AOD, for a number of channel taps. In [13], it is proposed to report the channel impulse response to be able to exploit correlation information.

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| --- | --- |
| Source | Proposal |
| [21] | **Proposal #1:*** + **Support measured channel reporting per DL-PRS resource from UE to gNB to facilitate accurate DL-AOD estimation, including:**
		- **Complex channel coefficient *h*(*m*) = *A*(*m*) × exp(*jφ*(*m*)) for the *m*th propagation path (channel tap) per DL-PRS resource:**
			* ***A*(*m*) - channel amplitude for the *m*th propagation path; and/or**
			* ***φ*(*m*) – channel phase for the *m*th propagation path**
 |
| [13] | **Proposal 2: To improve the DL-AoD accuracy in UE-assisted mode, support enhanced UE measurements and reporting by considering the following:** * **Reporting additional correlation information (ex. CIR reporting)**
* **Reporting of the estimated first arriving path, multipath and noise power**
* **Reporting of timing measurements on the DL-PRS resources along with the RSRP report.**
 |

1. For DL AOD, support reporting of the measured complex channel, h(m) = A(m) × exp(jφ(m)) per path.
* FFS: details on the reporting (including whether to send phase and amplitude separately, quantization, number of paths, etc)

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | The same view with LOS/NLOS, we propose to discuss it after multipath mitigation is in WID |
| Huawei/HiSilicon | Support. |
| ZTE | It’s unclear what’s the benefit of reporting phase and amplitude together. Regarding the amplitude and multipaths, it can be discussed in proposal 2. |
| CATT | Support. Rich measurement report will help LMF to improve the positioning accuracy. |
| Intel  | Support. |
| Qualcomm | Is this proposal trying to enable a phase-difference based DL-AOD, rather than an RSRP-based AoD? Wouldn’t it make more sense to enable this in UE-based and avoid all the reporting overhead? Have companies performed comparison or overhead / performance analysis to understand what is being discussed here? We are talking about raw channel reporting here, a feature that has been discussed over a variety of different WIs, releases, and contexts; and hasn’t been specified.  |
| Apple | Assuming that PRS-RSRP measurements associated to path is specified, then the benefit of CIR reporting is unclear…  |
| Ericsson | Support the principles. But we share the concern on overhead.  |

### Aspect #6 extension of number of reported RSRP measurements

#### Summary and FL proposal

In [4], it was proposed to increase the maximum number of measurements per TRP, in order to account for different RX beam. in [5] it is propose to either fix the RX beam for the 8 reported PRS RSRP, or introduce a new list of PRS Rx Beam indices to map the measurements to Rx beams.

|  |  |
| --- | --- |
| Source | Proposal |
| [4] | ***Proposal 2: The maximum number of RSRP measurements per TRP for DL-AoD positioning should be increased for reporting the RSRP measured from different RX beams.*** |
| [5] | ***Proposal 5**** ***To improve the accuracy of AoD and to avoid the impact of Rx beam, choose one of the following options.***
* ***Option 1: Report up to 8 DL PRS-RSRP corresponding to the same RX beam index***
* ***Option 2: Adding an additional DL PRS-RSRP list with different nr-DL-PRS-RxBeamIndex for a PRS resource.***
 |

1. For DL AOD, the RSRP measurements per TRP is reported for
* Option 1 : up to 8 measurements per TRP per Rx beam index. Multiple measurements corresponding to different Rx Beam index may be reported for a given PRS.
* Option 2 : up to 8 measurements per TRP, for the same Rx beam index
* Option 3: up to N>8 measurements per TRP for all Rx beam indices, Multiple measurements corresponding to different Rx Beam index may be reported for a given PRS.

 FFS: value for N.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | 1, Option 1 seems to consider UE RX beam sweeping for a fixed TRP TX beam. We doubt the benefit when comparing with TRP TX beam sweeping for a fixed UE RX beam. Also the UE orientation may change with time, so the RX beam direction changes also. As such we don't see the benefit of this option2, For option 2, in rel-16 we think we already agree and it is a common understanding to fix RX beam for multiple RSRP measurements3, the angle granularity is determined by a vector with several differential RSRP elements, because different angle may correspond to a different vector. As long as UE is to fix the receive beam, the multiple differential RSRP values can be used to determine the direction. We don't think it is meaningful to change RX beam for measurement  |
| vivo | In general, we are okay with all three options and slightly prefer option2 or option3. Option 3 is better for achieving optimal performance based on our evaluation, but if consider latency, option 2 is better. |
| Huawei/HiSilicon | OK. |
| ZTE | This could be the scope of Rx beam enhancements, we suggest to discuss this in proposal 5. |
| CATT | Support. We prefer Option 3.  |
| Intel  | Do not support. It is not clear for us, how the RX beam index can be taken into consideration since the orientation of the UE in space is not known and it may change in time.  |
| Lenovo, Motorola Mobility | Open to support option 1 and 3 since this takes into account a UE’s general orientation with respect to the gNB, however there can be a possibility of high UE reporting overhead especially for cases where the UE rapidly and drastically changes orientation. Option 2) seems to be Rel-16 operation. |
| Qualcomm | We are open discussing increasing the number of RSRP measurements in a single report. For example, we may want to include multiple RSRPs for the same TRP across multiple timestamps in a single report. Suggest to keep the proposal more general for this first meeting:***For UE-assisted DL AOD, support enhancements to increase the number of RSRP measurements per TRP (PRS-ID) a UE can include in a single measurement report.*** |
| Apple | If the intention is to have more diverse RSRP report for different RX beams, as we commented in previous proposal the benefit of such UE’s Rx knowledge at LMF is unclear.  |
| Ericsson | Since the benefits of extending the reporting to more than 8 beams is not clear yet, we propose to keep all options for now and down-select in future meetings.  |
| DOCOMO | We have similar view as Ericsson. |

###  Aspect #7 Signalling to assist reference UE calibration

#### Summary and FL proposal

In [4], it was proposed to support calibration by a reference UE, by allowing to send measurement and location coordinates of a reference UE, as well as TRP beam characteristics, to the LMF. In [12] it is proposed to use a reference node with a very accurate knowledge of the node location to

|  |  |
| --- | --- |
| Source | Proposal |
| [4] | ***Proposal 3: In order to improve DL-AOD estimation accuracy, the measurements provided by a reference UE with known locations should be supported to assist the calibration of the TRP transmitting beam direction.**** ***The measurements and location coordinates of the reference UE are reported to LMF***
* ***The transmitting beam characteristics of TRP should be reported to LMF***
 |
| [12] | *Proposal 3: Estimate the angle error by a reference node whose accurate location is known.* |

1. For DL AOD, support introducing high accuracy reporting of the UE location, for the purpose of supporting reference UEs.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Support it  |
| Huawei/HiSilicon | This could be covered by the generic device-assisted (FFS UE/TRP/other) timing/angle calibration. |
| CMCC | OK. |
| ZTE | It’s unclear to us what is the expected spec changes? In our understanding, the reference can be a UE or TRP. For the reference UE, the reporting mechanisms can be nothing different from normal UE. |
| Nokia/NSB | Agree with Huawei. To ZTE, there clearly need to be some changes to the current setup for a reference UE/device to be supported. At least the ability for UE/device to report capabilities (as it relies on reference location with very high accuracy) and combine the reference location with the measurements. There may also be signaling needed to/from the LMF to ensure that the calculated values can be used by TRPs/UEs to assist in future positioning calculations.  |
| CATT | Support. |
| Intel | Do not support.It needs to be considered as a part of the more general discussion, including UL-AOA and timing measurements. |
| Qualcomm | The spec already supports high accuracy positioning reporting, independent of method; so its unclear what is the first part of the suggested enhancement* Independent of that, if the purpose of this proposal is to support DL-AoD calibration procedures, we have a similar comment to the UL-AoA summary;
	+ Comment 1: we can just talk about a “reference node/device/entity” and not specifically a UE for now. A gNB could also measure PRS (and has an accurate knowledge of its information all the time). It could eventually be a UE that can be “attached” in the gNB as it is the case in IAB, etc. We prefer to discuss these details later.

Having a generic notion of “reference node/device/entity” for RAN1’s discussion would enable using it for calibration of other methods, like the timing errors in 8.5.1 and UL-AoA. Having a unified and forward-looking approach should be preferred.  |
| Apple | Support the intention |
| Ericsson | Do not support. Reference UE’s locations can be acquired via a proprietary solution.  |

## gNodeB signalling aspects

### Aspect #8 beam orientation error handling

#### Summary and FL proposal

Several contribution propose to account for the beam orientation error in the gnodeB[5][7].

|  |  |
| --- | --- |
| Source | Proposal |
| [5] | ***Proposal 3**** ***Beam orientation errors and potential correction mechanisms need to be considered in R17.***
 |
| [7] | **Proposal 1:** RAN1 to study beam orientation errors and potential correction mechanisms in order to improve the positioning accuracy achievable with DL-AoD. Including:* UE-based positioning: the beam offset (BO) could be signaled to the UE, as either an indicator, e.g. low/medium/high, each specifying an error range or as a specific value computed by the network
* UE-assisted positioning: LMF should be aware of the BO and compensate for the errors when computing the position estimate.
* Signaling aspects:
	+ LMF signals to TRPs that a BO recomputation and beam re-tuning is needed.
	+ UE measurement reports to facilitate BO identification and potential correction.
 |
| [18] | ***Proposal 3: Support mechanisms to consider beam orientation impairments and related assistance information for improving DL-AoD positioning accuracy.*** |

1. Support mechanisms to consider beam orientation impairments and related assistance information for improving DL-AoD positioning accuracy.
	* FFS: gnodeB and UE signalling to support beam orientation impairements mitigation.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Support |
| Huawei/HiSilicon | This could be covered by the generic device-assisted (FFS UE/TRP/other) timing/angle calibration. |
| ZTE | Not support. In our view, if gNB has the prior information of beam errors, gNB can adjust beam direction in advance rather than inform this to UE. |
| Nokia/NSB | Same comments as on aspect 2.1.7. |
| CATT | Support. |
| Intel | Do not support.We think that it can be done by implementation. Additionally, we belive that overall calibration aspects are in the scope of RAN4. |
| Lenovo, Motorola Mobility | Support |
| Qualcomm | * Unclear on the meaning “mechanisms for beam orientation impairments”. Is that the same as the calibration procedures in the previous proposal? If not, can we be more specific?
* We are supportive of assistance information enhancement (for both UE-based and UE-Assisted) to support beam orientation impairment mitigation.
 |
| Apple | The intention is unclear, basically what does this proposal bring on top of the previous proposal! |
| Ericsson | Do not support, we see this as an implementation issue.  |

### Aspect #9 gNodeB beam Shape information signalling

#### Summary and FL proposal

in [5][6] [11] [13] [14] [17], it is proposed to have the gnodeB transmit additional beam information to the LMF or the UE for AOD enhancements. In [4] it was proposed to support calibration by a reference UE, by allowing to send measurement and location coordinates of a reference UE, as well as TRP beam characteristics, to the LMF.

|  |  |
| --- | --- |
| Source | Proposal |
| [4] | ***Proposal 3: In order to improve DL-AOD estimation accuracy, the measurements provided by a reference UE with known locations should be supported to assist the calibration of the TRP transmitting beam direction.**** ***The measurements and location coordinates of the reference UE are reported to LMF***
* ***The transmitting beam characteristics of TRP should be reported to LMF***
 |
| [5] | ***Proposal 2**** ***Report additional beam information to the LMF or the UE for the enhancement of AoD.***
	+ ***E.g. intersection point of multiple beams:*** $\left(angle ,RSRP\right)\_{intersection point}$
 |
| [6] | ***Proposal 6***: Consider reporting beam-shape information to the UE for DL-AoD techniques. |
| [11] | **Proposal 3: Support the enhancement of reporting the gNB beam information to the LMF. FFS the details of what/how to report the beam information.** |
| [13] | **Proposal 1: Introduce the possibility to report the radiation characteristics of the transmitted PRS resources (i.e. main lobe power-level, sidelobe level, etc.).** |
| [14] | **Proposal 2-1**: It is preferred to have a table provided by each TRP which may characterize all the beam responses (EIRP) for covering a range of angles. The table is like a look-up table when UE reports a number of differential RSRP values for finding the angle between a TRP and UE**Proposal 2-2**: A look-up table with differential EIRP across beams for a range of angles could also be considered |
| [17] | ***Proposal 1: For the purpose of enhancements to the RSRP-only DL-AoD method, support the signaling of beam responses (or equivalent information) to increase the accuracy precision while ensuring a tractable signaling overhead for both UE-based and UE-assisted solutions.**** ***Note: For UE-Based AoD, the above signaling enhancements correspond to assistance data signaling (unicast or broadcast). For UE-Assisted DL-AoD, the above signaling enhancements correspond to NRPPa signaling enhancements from gNB to LMF.***
 |

1. Support the enhancement of reporting the gNB beam information to the LMF.
	* FFS the details of what/how to report the beam information.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | support |
| vivo | Support |
| Huawei/HiSilicon | We think the specification impact is large compared to the proposal 10, and we consider it lower priority. |
| CMCC | We believe that the principle can bring benefits; however, it is mentioned by several companies that the signaling overhead would be huge.  |
| ZTE | Agree in principle. Leave details to next meeting when WID scope is stable. |
| Nokia/NSB | We are open to discuss but perhaps the signaling details to consider the overhead should be discussed before fully agreeing to support it.  |
| CATT | Support. |
| Intel  | We think that it is more complex solution compared to the DL-AOD reporting.  |
| Lenovo, Motorola Mobility | Open to Support. |
| Qualcomm | It is within scope of the WI to include enhancements for both UE-B and UE-A DL-AOD. Enhancement of gNB beam information should be applicable towards both the UE and the LMF. Support the enhancement of reporting the gNB beam information to the LMF (UE-assisted) and the UE (UE-based). **FFS the details of what/how to report the beam information.**  |
| Apple | Support the intention. |
| Ericsson | Agree with nokia, overhead should be considered before fully agreeing.  |
| DOCOMO | We are supportive and agree with the necessity of overhead discussion mentioned by some companies. |

### Aspect #10 gnodeB based calculation of AOD

#### Summary and FL proposal

In [21], it was proposed to have the gnodeB report the calculated AOD to the LMF, using received measurement from the UE. The proposal relies on a companion proposal to support complex channel reporting from the UE to the gnodeB. In [2] it was proposed to support mechanisms to have the LMF request the gnodeB to calculate the AOD.

|  |  |
| --- | --- |
| Source | Proposal |
| [21] | * + **Support DL-AOD reporting from gNB to LMF (or from gNB to UE), including:**
		- ***φ* – azimuth angle of departure**
		- ***θ* – zenith angle of departure**
 |
| [2] | ***Proposal 1: Support LMF to request angle calculation to the gNB for DL-AoD in Rel-17, i.e. the following Option from R3-197794.**** ***The RAN nodes calculate the AoD with the RSRP information based on gNB configuration and send the AoD information back to LMF, who then calculates the UE position.***
 |

1. DL-AOD reporting from gNB to LMF (or from gNB to UE) is supported

FFS: details on the report content

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Do not support.For us, we prefer P9. Because P9 only needs one-time assistance data request and response between LMF and gNB for all Ues, but P10 needs AoD request and report between LMF and gNB for each measurement of every UE. |
| Huawei/HiSilicon | Support. |
| CMCC | To our understanding, it avoids the complication of reporting detailed beam information to the LMF. Meanwhile, other details such as how does the serving TRP obtain the DL-AoD of neighboring TRP (maybe from neighboring gNB) should also be further considered. |
| ZTE | Not support. DL-AOD measurement report is from UE to LMF in Rel-16, this would lead to large spec impact. If the intention is to provide beam-shape information, it can be discussed in proposal 9. |
| Nokia/NSB | We prefer not to reopen what was a long discussion during Rel-16 and in addition the decision (which this would overturn) was not made in RAN1.  |
| CATT | Support. |
| Intel  | Support.  |
| Qualcomm | Unclear why we need to enhance DL-AOD in this direction: We already send the measurements to the LMF (NR rel-16). We either way, need additional assistance data (e.g. beam information) to be sent to the LMF to enhance this legacy method and to support UE-B DL-AoD. Why send the measurements to the LMF, and then the LMF send them to the gNB? Why not having the gNBs sending the beam information to the LMF (rather static information), so not really a big overhead.  |
| Apple | Do NOT support. We share similar view as ZTE |
| Ericsson | Do not support. The specification impact of such a decision is not reasonable, and as other companies mentioned the architecture of AOD was discussed at length by ran2 and ran3 to conclude that the LMF was the suitable node (R3-197794)  |

### Aspects #11 TRP antenna Array configuration signalling

#### Summary and FL proposal

In [21] and [17], it is proposed to provide additional information on the TRP antenna array configuration.

|  |  |
| --- | --- |
| Source | Proposal |
| [21] | Proposal 4* + **Support reporting of two DL-AOD azimuth angles *φ* and (π – *φ*) in addition to the zenith angle *θ* from gNB to LMF (or from gNB to UE)**

Proposal 5 **(Alternative to Proposal #4)*** + **Specify the TRP antenna array orientation in the local coordinate system**

Proposal 6* + **Support DL-AOD *φ’* = arcsin(sin(*φ*)×sin(*θ*)) angle reporting for the linear horizontal array, where *φ* is the azimuth angle of departure and *θ* is the zenith angle of departure**
	+ **Further discuss if it is necessary to indicate information on antenna array structure/type**
 |
| [17] | ***Proposal 2: For the purpose of enabling a phase-difference-based DL-AoD method, support the following signaling enhancements:**** ***gNBs’ UPA antenna Configuration, PMI Codebook configuration & their association to the transmitted PRS resources***
* ***Note: Enhancement should be applicable to both UE-based and UE-assisted DL-AoD***
 |

1. For both UE-based and UE-assisted DL-AoD, and for the purpose of supporting linear horizontal array types of gnodeB antenna configuration, consider the following options:
	* Support reporting of two DL-AOD azimuth angles *φ* and (π – *φ*) in addition to the zenith angle *θ* from gNB to LMF (or from gNB to UE)
	* Specify the TRP antenna array orientation in the local coordinate system
	* Support DL-AOD *φ’* = arcsin(sin(*φ*)×sin(*θ*)) angle reporting for the linear horizontal array, where *φ* is the azimuth angle of departure and *θ* is the zenith angle of departure
	* Support of signalling gNBs’ UPA antenna Configuration, PMI Codebook configuration & their association to the transmitted PRS resources

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | This proposal is not clear. Are all the sub-bullets supported for the purpose of ‘supporting linear horizontal array types of gNB antenna configuration’ in the main bullet ? Further clarification may be needed. For the first sub bullet, could proponents explain which type of panel can receive the signal from both the front side and backside? |
| Huawei/HiSilicon | The first bullet has some overlap with angle ambiguity in ePos-02. We suggest to make it general.The second bullet, we wonder why would the LCS setup based on TRP array orientation.The third bullet, we think, depends on whether gNB can report the angle calculation back to LMF, i.e. Aspect #9 (Second one, should be Aspect #10) is the premise.The four bullet, to our understanding, has some overlap with Aspect #9 (First one). If the beam shape overhead can be reduced using parameterized configuration. |
| ZTE | Our understanding is that the beam-shape information is highly related antenna configuration. So, we should decide first whether beam-shape related enhancement is supported or not. |
| Nokia/NSB | We think it is hard to group/discuss these different proposals into one big proposal.  |
| CATT | It looks like there are some overlaps between this proposal with previous proposals. We prefer to narrow down the proposal. |
| Qualcomm | * The support of signaling of the antenna config, & codebook confirmation is not for the purpose of ULA. It is assistance data enhancement for DL-AoD for the purpose of enabling phase-difference-based AoD.
* For UE-A DL-AoD, the gNB does not report an AoD to the LMF, so I am confused about the first subbelt.
* I thought the discussion here can be more generic. Do we see reasons of having better knowledge of the TRP antenna configuration/orientation at the LMF or the UE?
	+ At least from our side, such a knowledge, together with a mapping of PRS resources into the antenna configuration (similar as it is happening for CSIRS) would enable a phase-difference-based DL-AoD and determining the DL-AoD directly at the UE.
 |
| Apple | Open to further discuss, maybe with lower priority. |

## Other Aspects for discussion

The following aspects have been proposed by one company. It is proposed to delay discussion on these issues to give a chance to other companies to consider these issues in future contributions.

### Aspect #8 Differential angle reporting

In [15] it was proposed to study angle difference measurement for the AOA of DL PRS.

|  |  |
| --- | --- |
| Source | Proposal |
| [15] | ***Proposal 2: Support differential beamforming technique for DL-AOD positioning methods.*** ***Proposal 3: aspects of PRS resource configuration, DL transmission beam indication and UE measurement and report needs to be considered in order to support differential beamforming technique for DL-AOD positioning methods.***  |

### Signalling of preferred SSB

In  [8], it is proposed that the you may signal the preferred SSB to obtain timing mesasurements.

|  |  |
| --- | --- |
| Source | Proposal |
| [8] | ***Proposal #4:**** Support enhancements to enable the UE can use the reception beam in a direction corresponding to the minimum propagation time.
	+ E.g., the reporting of the preferred SSB to obtain timing measurements.
 |

### UE specific beam refinement

In [1] and [6] it was proposed to support configuring UE specific beam refinement on DL PRS resouces:

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | Proposal 1: To enhance the performance of DL AoD, support UE-specific beam refinement on DL PRS resource for DL-AoD measurement. |
| [6] | ***Proposal 5***: Consider two stage beam-sweeping for DL-AoD to improve angular resolution in a time and power efficient manner. |

### UE orientation reporting

In [9], it was proposed to include the UE orientation in the information reported to the LMF from the UE.

|  |  |
| --- | --- |
| Source | Proposal |
| [9] | **Proposal 2: The UE should report its orientation information to the LMF.****Proposal 3: Define conditions for the UE to report the orientation.** |

### UE panel ID reporting

In [9], it was proposed to include the UE panel ID in the information reported to the LMF from the UE.

|  |  |
| --- | --- |
| Source | Proposal |
| [9] | **Proposal 1: Include Rx panel ID in the measurement report.** |

# Conclusion

TBA

# References

1. R1-2100130 Enhancements for DL-AoD positioning OPPO
2. R1-2100238 Enhancement for DL AoD positioning Huawei, HiSilicon
3. R1-2100295 Accuracy improvements for DL-AoD positioning solutions ZTE
4. R1-2100387 Discussion on accuracy improvements for DL-AoD positioning solutions CATT
5. R1-2100447 Discussion on potential enhancements for DL-AoD method vivo
6. R1-2100489 Discussion on improving the accuracy of DL AoD positioning solutions FUTUREWEI
7. R1-2100550 Initial views on enhancing DL AoD Nokia, Nokia Shanghai Bell
8. R1-2100710 Discussion on accuracy improvement for DL-AoD positioning LG Electronics
9. R1-2100750 Accuracy improvements for DL-AoD positioning solutions InterDigital, Inc.
10. R1-2100864 Discussion on accuracy improvements for DL-AoD positioning method Sony
11. R1-2101048 Discussion on DL-AoD enhancement CMCC
12. R1-2101121 Accuracy improvements for DL-AoD positioning solutions Xiaomi
13. R1-2101133 DL-AoD positioning enhancements Fraunhofer IIS, Fraunhofer HHI
14. R1-2101141 Accuracy enhancement for DL-AOD technique MediaTek Inc.
15. R1-2101212 Accuracy improvements for DL-AoD positioning solutions Samsung
16. R1-2101388 Accuracy enhancements for UL-AoD positioning technique Apple
17. R1-2101470 Potential Enhancements on DL-AoD positioning Qualcomm Incorporated
18. R1-2101501 Potential DL-AoD Positioning Enhancements Lenovo, Motorola Mobility
19. R1-2101618 Discussion on DL-AoD positioning enhancements NTT DOCOMO, INC.
20. R1-2101756 Enhancements of DL-AoD positioning solutions Ericsson
21. R1-2100659 NR positioning enhancements for DL-AoD method Intel Corporation